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30th November 1956.

Numerical forecasts based on objectively analysed data

by

Vera M. Huckle

(Meteorological Office)

AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

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1. Introduction

Four numerical forecasts have been calculated on data objectively analysed by the technique explained by Bushby (1956). The data for the 500 mb level and the 1000-500 mb thickness were analysed using the quadratic surface method with $p = p_2$, $q = \frac{1}{16} p_2$ and $T^2 = 16$ sec^2. The object in doing these calculations was to discover whether or not the standard of the forecast charts would be seriously affected by using objectively analysed data instead of data analysed by the normal methods.

Forecasts for twenty-four hours were computed based on the two sets of data for each situation and each was compared with the actual chart for that time, analysed subjectively. For interest, the surface prebaratic prepared in the Forecast Division, Dunstable was also compared with the actual chart, although it is not the purpose of this paper to compare conventional forecasts with those produced by numerical methods. The three dates chosen were 1500 G.M.T. for 12th September, 15th October, 31st October, 1955 and 30th January, 1952. The two-parameter model of the atmosphere used was that which incorporates the sea surface heating effect and uses the actual boundary values.

2. Results

(a) 12th September, 1955.

On the actual 500 mb chart for 12.9.55 (Fig.1a) there was the suggestion of a double trough, the northern one to the west of the British Isles and the southern one over the British Isles. Twenty-four hours later (Fig.1c) there was a very broad irregular trough from Scotland across Europe to Italy, with still a slight suggestion of a double trough. There was a very strong flow down from Greenland to the British Isles . The computation (Fig.1e) based on subjectively analysed data gives a trough east of the actual position and not broad enough. There is a strong flow across the Atlantic from Greenland to the British Isles but it continues round the trough whereas there was actually a diffluence. The values of the contours are too high in the south-west of the area and over Ireland. The computation based on objectively analysed data also gives the heights too high, those over Ireland being higher than in the previous computation. As a result of this, the flow in the Atlantic is not strong enough. The trough is in the right position and is very broad, but due to the height error it appears as a shallow trough and the double trough is over-emphasised.

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On the actual 1000-500 mb thickness charts (Figs.1b and 1d), a broad trough just west of the British Isles became stronger and moved to the east of the British Isles, a ridge forming in the Atlantic, south of Greenland. The computation (Fig.1f) based on subjective analysis gives a ridge over southern Greenland and a broad trough over the British Isles with small scale oscillations superimposed on it. These may be due to computational instability. The values of the height agree fairly well with the actual chart. The chart (Fig.1h) produced from objectively analysed data is very similar to the one mentioned above. The irregularities are more marked and the thickness is about 200 feet out over the British Isles.

On the 1000 mb charts (Fig.1b and 1d) there was an almost stationary anticyclone in the Atlantic with a depression moving south-east from Iceland. There were two troughs associated with the depression, one being a frontal trough and one connected with the thickness trough. The computation (Fig.1f) based on subjectively analysed data gave an anticyclone of the right intensity in the right position and a depression of the right intensity but this was moved too far east. Two troughs appeared but they were not emphasized enough. The objective analysis produced a similar chart (Fig.1h). The frontal trough was correctly placed and there was a more pronounced ridge over the Low Countries. The values were too high over the British Isles in both computations, that based on objectively analysed data giving the higher values.

(b) 15th October, 1955.

At the 500 mb level (Fig.2a) there was a cut-off high cell centred about 49°N 22°W with a ridge extending up to Greenland and one in an easterly direction into France. There was a strong flow from Greenland over Iceland to the British Isles with a trough from Norway to the British Isles. During the following twenty-four hours (Fig. 2c) the high cell declined leaving a weak ridge. The low and associated trough from Norway broadened out and the flow slackened. The computation (Fig.2c) based on a subjective analysis of the data did not show the weakening of the Atlantic cut-off high and ridge but kept the ridge in approximately the right position. There was a broad trough over Europe but it was distorted by small scale disturbances. The low over the Baltic was computed to be too deep. The computation (Fig.2g) based on data analysed objectively had similar faults, although the distortions on the European trough were not so pronounced. The thickness chart (Fig.2b) had originally a ridge over the south-west Atlantic with a confluent trough over the east of the British Isles. By the next day (Fig.2d) the thermal gradients round the trough had become more uniform and the trough had broadened. Both the computed charts suffered from computational instability to a marked extent. Both forecasts gave a broad trough but the small scale disturbances make comparisons very difficult. The computed 1000 mb charts do not show marked instability and are very similar.

The instability produced could have been caused by the specification of vorticity on the boundary at points where fluid is leaving the region, or by the time step chosen being too long in relation to the grid length and the wind speed. To gain more information, the computation was repeated using subjectively analysed data and half-hourly time steps instead of hourly ones. The charts produced were practically identical with those produced previously. Therefore, the instability, if it is computational, must be due to the boundary conditions imposed. Since there is a very strong flow across the north-east boundary, this is very probable.

(c) 31st October, 1955.

On the original 500 mb chart (Fig.3a) there was a trough over the Atlantic extending SSW. from Iceland with an irregular flow round it. A second trough was situated over the Baltic with a low latitude trough over the Pyrenees. Twenty-four hours later (Fig.3c) the Atlantic trough was in two sections, a progressive trough in the north with a slack gradient in the centre, and a stationary one in the south, west of the Azores. The Baltic trough moved

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out of the area and the one over Spain filled and moved a little eastwards. The computation (Fig.3a) based on subjectively analysed data gave only one trough in the Atlantic with slack central gradient. The trough over Spain was smoothed out. Values of the 500 mb contour height were in good agreement with the actual values but the 18200 feet contour was placed too far north over Europe. The computation (Fig.3g) based on objectively analysed data gave two troughs in the Atlantic, one progressive and one not, but the progressive one had no slack gradient at the centre. A trough was left over Europe, but it had the wrong orientation. The contour heights were in good agreement with the actual values but the low over Iceland was not made quite deep enough.

The original thickness chart (Fig.3b) had a trough extending from Iceland to the south-west with another one over the Baltic, and the suggestion of one over England, these two being in higher latitudes - the lower latitudes having one broad trough. Twenty-four hours later (Fig.3d) there was a stronger trough slightly east of the original one and another one over England going down through Biscay to Spain. The computation based on subjectively analysed data (Fig.3f) gave a trough in the Atlantic in approximately the right position but wrongly orientated. There was a very pronounced ridge over England with a slight trough in the 18000 feet contour. The objectively analysed data resulted in a chart (Fig.3h) giving a trough in the Atlantic in the right position but of wrong shape. The ridge that was west of Iceland has been moved too far east placing it over the British Isles and the trough, which in this computation is in the 17800 feet contour, is also too far east. In both computations the thickness is too high in the region of the British Isles.

The 1000 mb contour chart had two depressions on the Atlantic, one south of Iceland and one west of the Azores, with an anticyclone over England and a depression over the east coast of Spain. During the following twenty-four hours, the two Atlantic depressions became important, the southern one moving and the northern one remaining stationary. They both deepened considerably, the one near Iceland becoming a vigorous one with a central closed contour of -600 feet. The anticyclone over England moved eastwards and the low over Spain remained the same. The computation based on subjectively analysed (Fig.3g) data did not move either of the Atlantic depressions and did not deepen either of them sufficiently, although the one near Iceland was deepened by 300 feet. The anticyclone over England was moved eastwards correctly but intensified as well. The low over Spain was not substantially altered, the area of low pressure becoming greater. The second computation (Fig.3h) was very similar to the first. The depression south of Iceland was made slightly deeper than in the previous computation but was still not deep enough and it was also placed too far east.

(d) 30th January, 1952.

This case has been computed using several variations of the basic two-parameter method. The computation based on subjectively analysed data using the same method as was used for the other three cases mentioned in this report is reported by Bushby and Huckle (1956). The computation has now been performed on objectively analysed data. At 500 mb the computation based on subjectively analysed data (Fig.4e) has a strong jet stream terminating in a diffluent trough that is much too far east. The jet stream is not intense enough and is too far north. Over Southern England, the heights are 1200 feet too high. When the computation was repeated on objectively analysed data (Fig.4g) the diffluent trough was placed much nearer its actual position. The jet stream is still not intense enough and too far north, the height over Southern England in this case being 1000 feet too high. In the computation based on subjectively analysed data (Fig.4f), the axis of the thickness trough was computed to be too far north and east and not curving enough and the ridge near it was also wrongly situated and shaped. In the computation based on objectively analysed data (Fig.4h) the position and shape of the trough and ridge are very near the actual position and shape. The values are only 400 feet too high over the British Isles.

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The computation based on subjectively analysed data for 1000 mb (Fig.4d) gave a series of ridges and troughs right across the Atlantic, with the main trough over Europe and the ridge over the North Sea, instead of an almost straight flow across the Atlantic with a ridge west of Ireland and a trough over the North Sea. In the computation based on objective analysis of the data (Fig.4h) there was a much smoother flow across the Atlantic with a ridge over Ireland and a trough down the North Sea.

The earlier paper described the improvements in the forecast charts made by using a stream function. The improvements by this method and by the use of objective analysis were of different natures. It may be therefore that by using the stream function method on the objectively analysed data further improvements to the forecast would be made.

(e) Correlation coefficients.

Table 1. Correlation and regression coefficients.

Date 1500 GMT	Method of analysis	500 mb			1000- 500 mb			1000 mb		
		r	a	b	r	a	b	r	a	b
12.9.55	Subjective	0.95	0.96	-3.40	0.91	1.10	0.70	0.87	0.72	-3.50
	Objective	0.92	0.71	-4.30	0.85	1.04	-1.14	0.89	0.92	-3.50
15.10.55	Subjective	0.82	0.98	-6.9	0.90	0.77	-5.4	0.81	0.90	-3.60
	Objective	0.90	0.99	-8.4	0.88	0.74	-4.2	0.81	0.92	-6.60
31.10.55	Subjective	0.93	1.21	-8.1	0.83	1.01	-5.37	0.86	1.29	1.65
	Objective	0.92	1.14	2.09	0.85	0.91	-3.80	0.85	1.30	8.56
30.1.52	Subjective	0.47	0.40	-28.20	0.72	0.69	-5.5	0.58	0.63	-26.9
	Objective	0.60	0.69	-35.20	0.86	0.72	-5.4	0.76	0.80	-31.6

r = correlation coefficient; a, b are the regression coefficients of the best fitting straight line giving the actual change (Y tens of feet) in terms of the forecast change(X tens of feet) in the form

$$Y = aX + b$$

where b is in tens of feet.

The correlation coefficients show little difference between the computations based on subjectively or objectively analysed data in three of the four cases considered. The fourth case however, 30.1.52, has noticeable improvements

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both as regards the actual charts and the correlation coefficients when the objectively analysed data are used instead of subjectively analysed data. In this case, the objective analysis method has given a forecast for 1000 mb comparable with that produced by the Forecast Division whereas the other numerical computation based on subjectively analysed data was not as good as the conventional one.

3. Conclusion

Four cases are obviously not enough on which to judge the success or failure of objectively analysed data as a basis for time integrations. They do show that it is a practical method which is quicker than a subjective analysis when the results are needed for numerical time integrations. The results indicate that small scale features tend to be lost with objective analysis although the main features remain. On one occasion the objective analysis of the data has resulted in better forecast charts. This may be due to the difficulty in drawing the lines accurately and in reading off the values accurately in regions of strong gradients.

It appears from these four cases that objectively analysing data for time integration work only slightly affects the resulting charts unless there are very strong gradients in the area, when the objective analysis technique may well provide a necessary degree of smoothing and thus produce better results as the final product.

References

Bushby, F.H.	1956	Meteorological Research Papers, Air Ministry, London, No. 986.
Bushby, F.H. and Huckle, V.M.	1956	Quart. J.R. Met. Soc., p.409.

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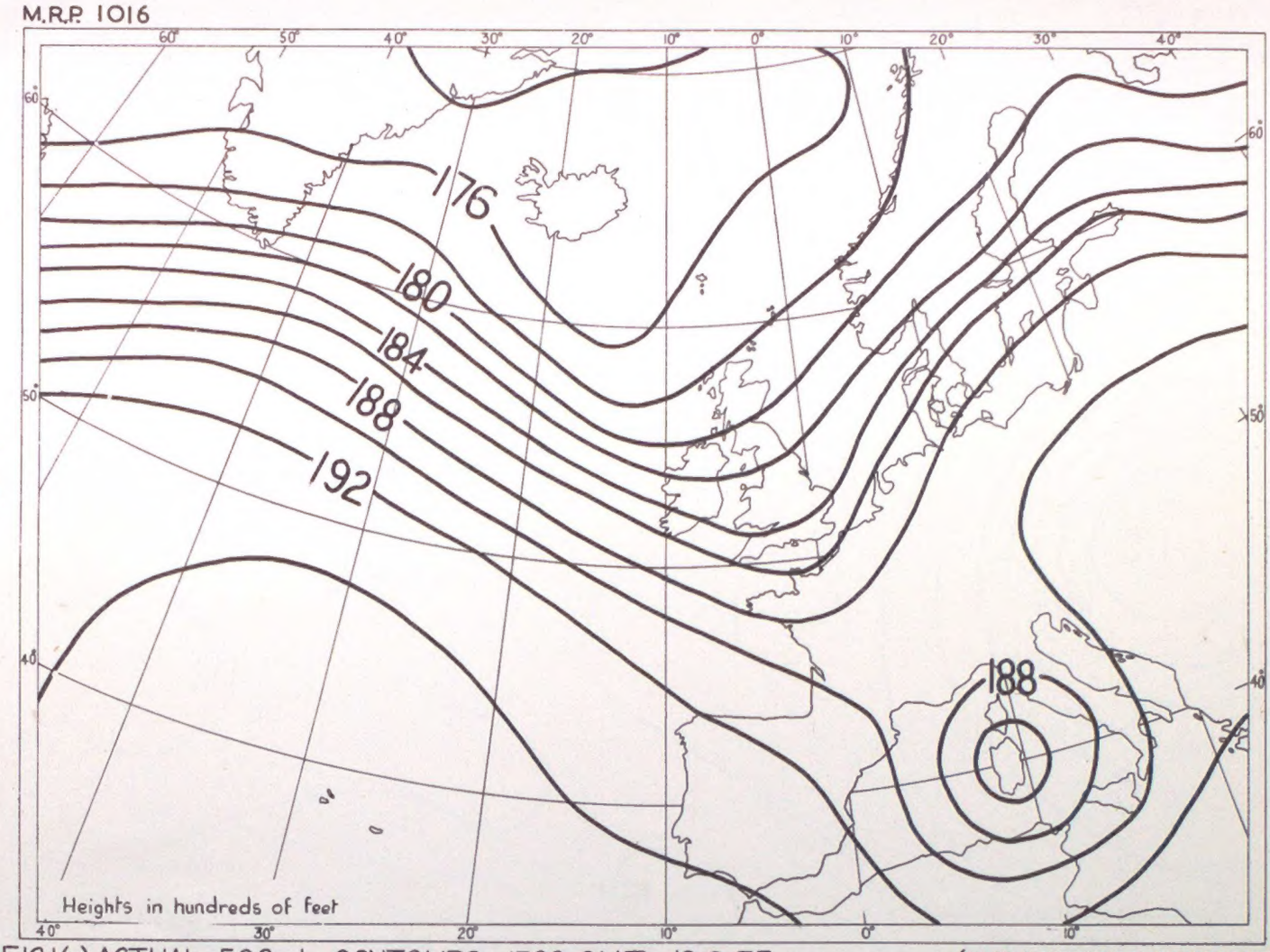

FIG.1(a) ACTUAL 500mb. CONTOURS, 1500 G.M.T. 12:9:55 (SUBJECTIVE ANALYSIS)

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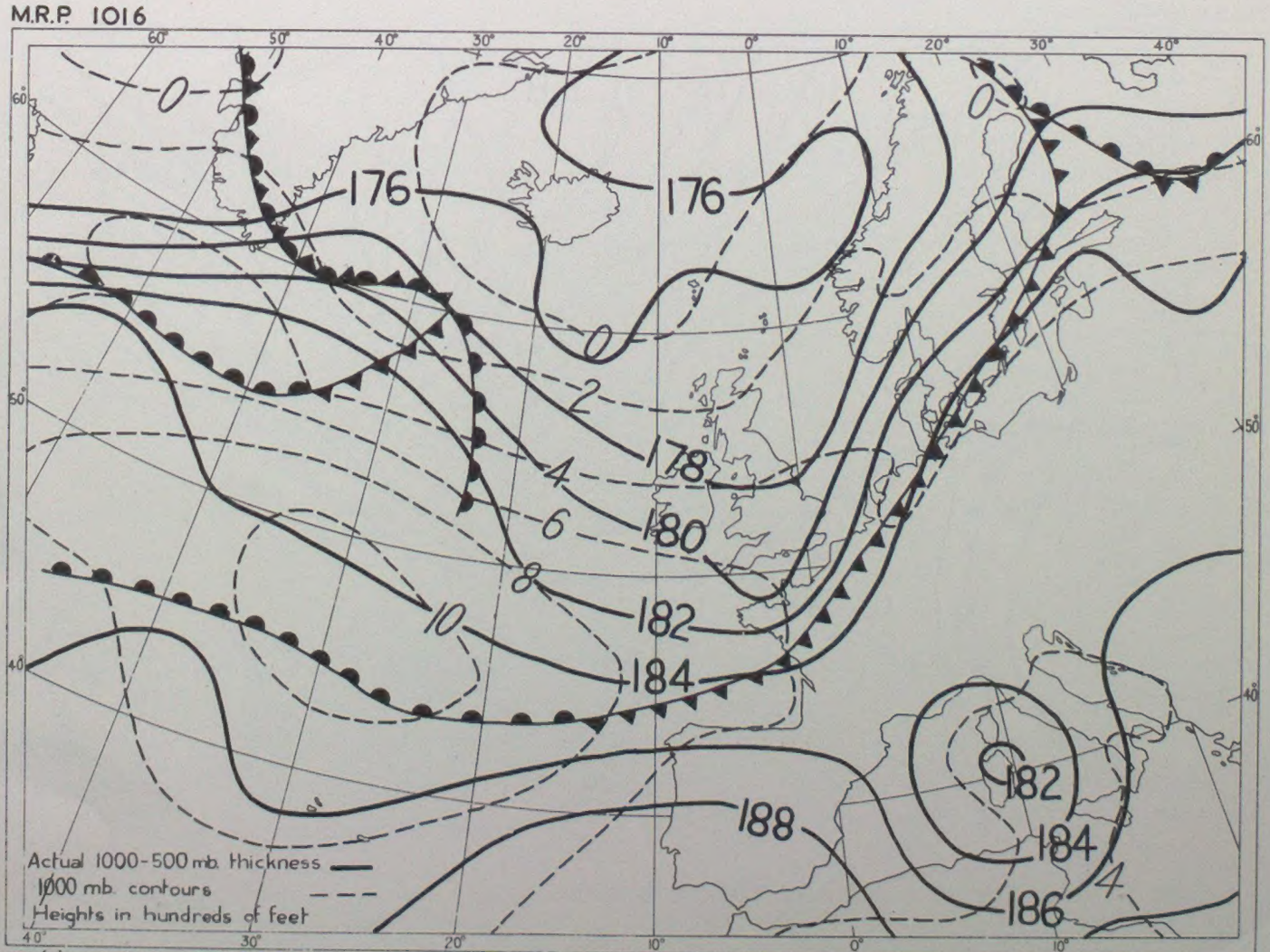

FIG 1(b) ACTUAL 1000-500mb. THICKNESS AND 1000mb. CONTOURS, 1500 G.M.T. 12:9:55 (SUBJECTIVE ANALYSIS)

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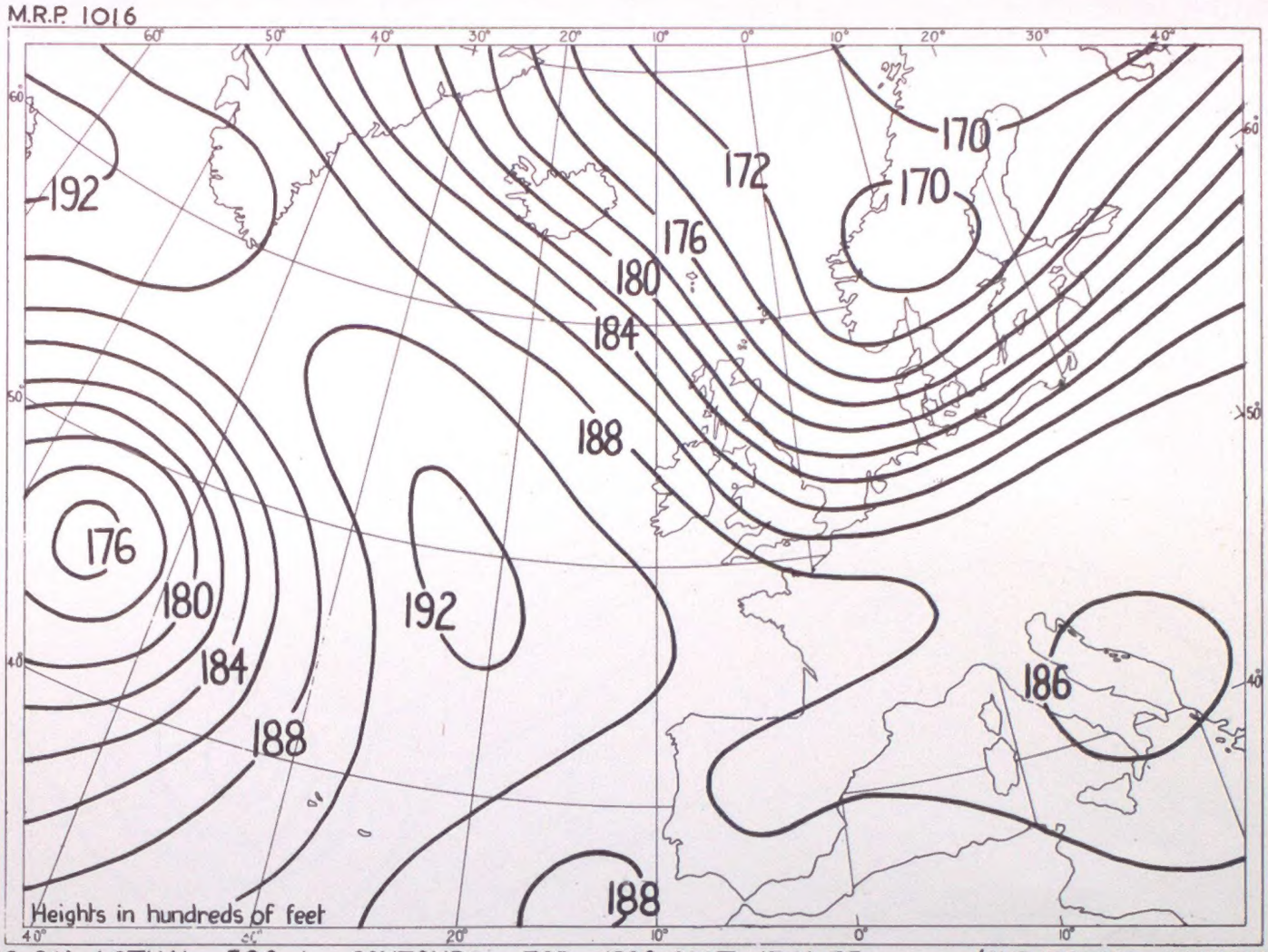

FIG. 2(a) ACTUAL 500mb CONTOURS FOR 1500 G.M.T. 15:10:55 (SUBJECTIVE ANALYSIS)

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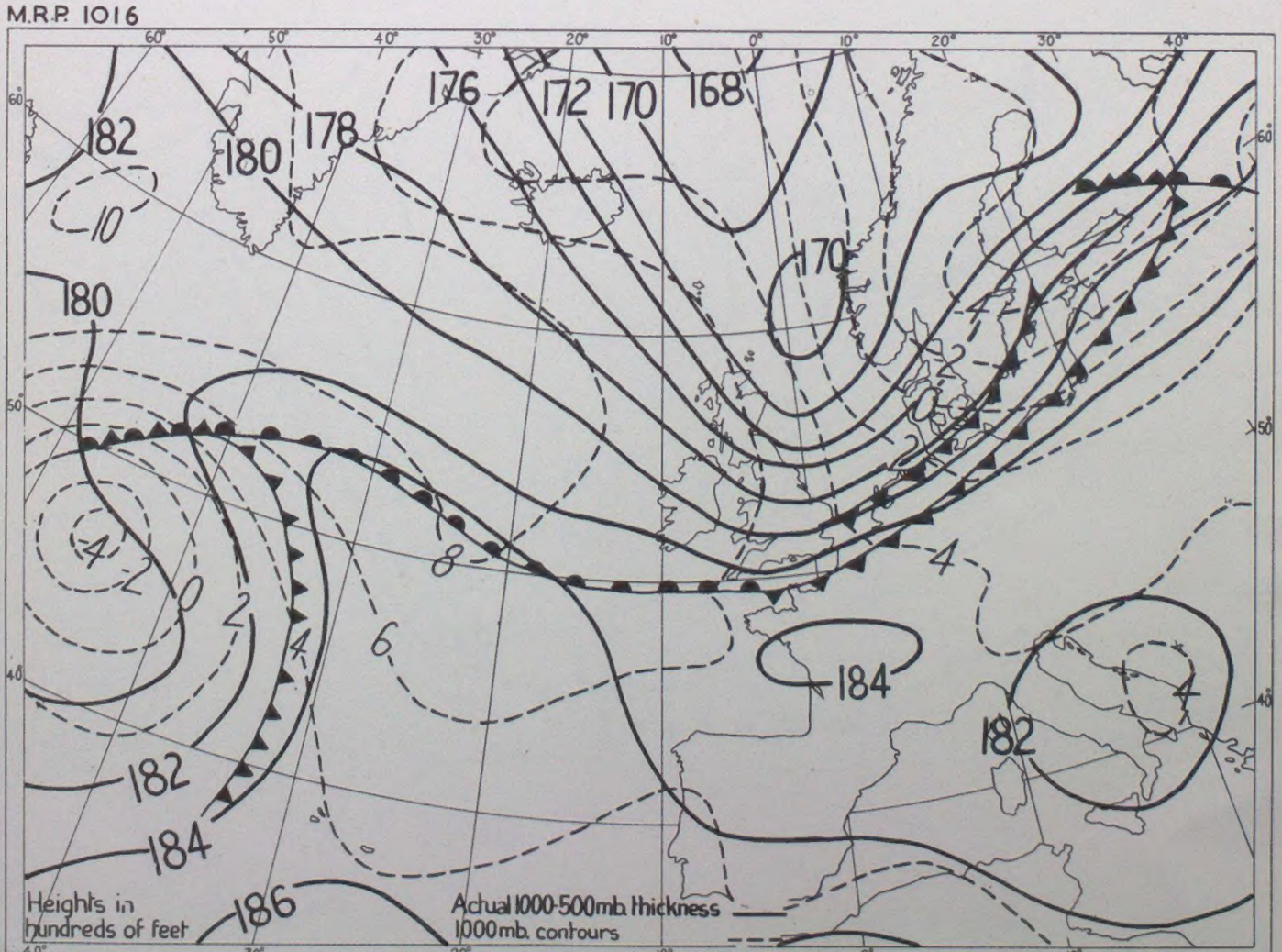

FIG. 2(b) ACTUAL 1000-500mb. THICKNESS AND 1000mb CONTOURS, 1500 G.M.T. 15:10:55 (SUBJECTIVE ANALYSIS)

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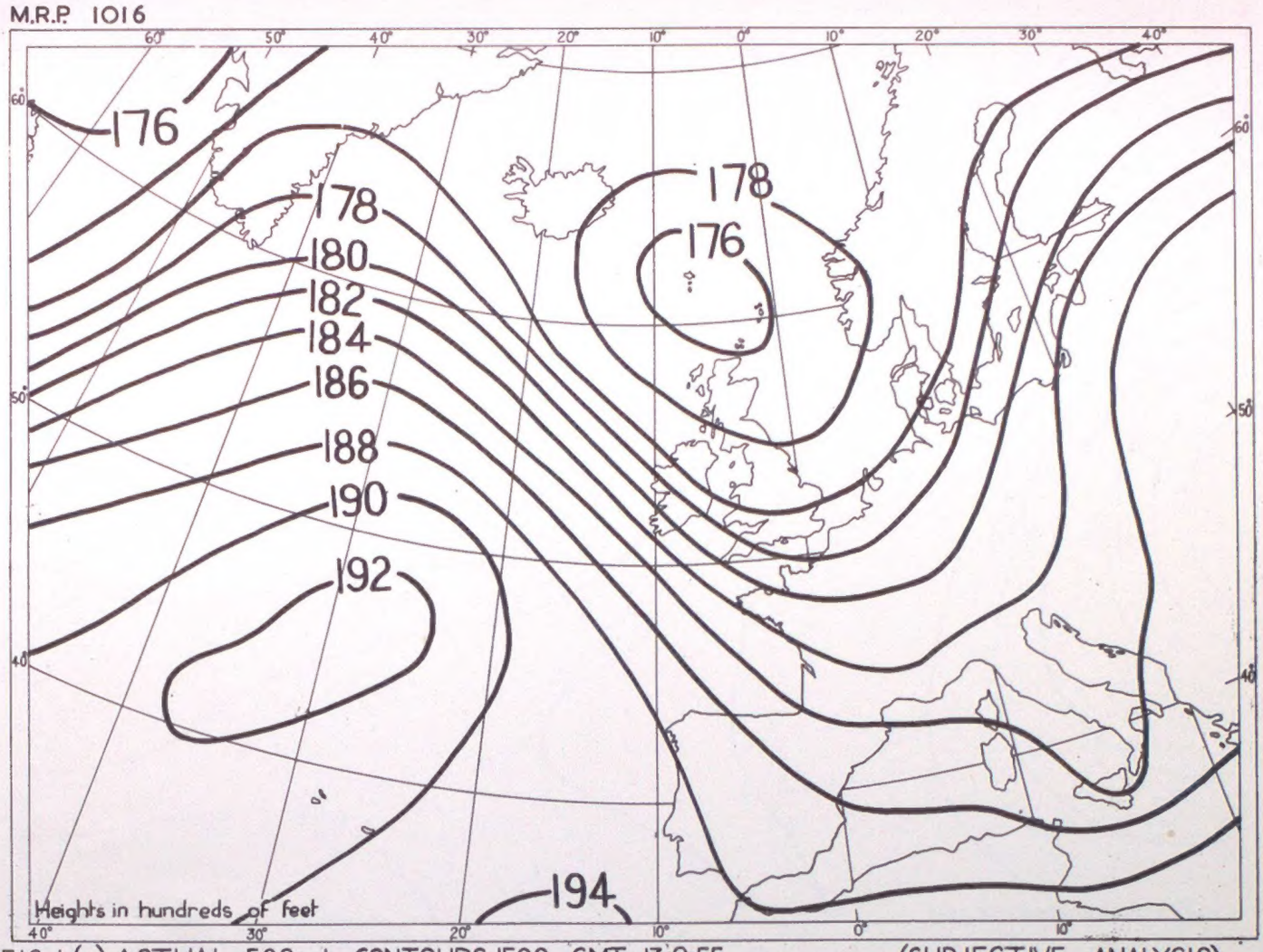

FIG. 1 (c) ACTUAL 500 mb. CONTOURS, 1500 G.M.T. 13:9:55 (SUBJECTIVE ANALYSIS)

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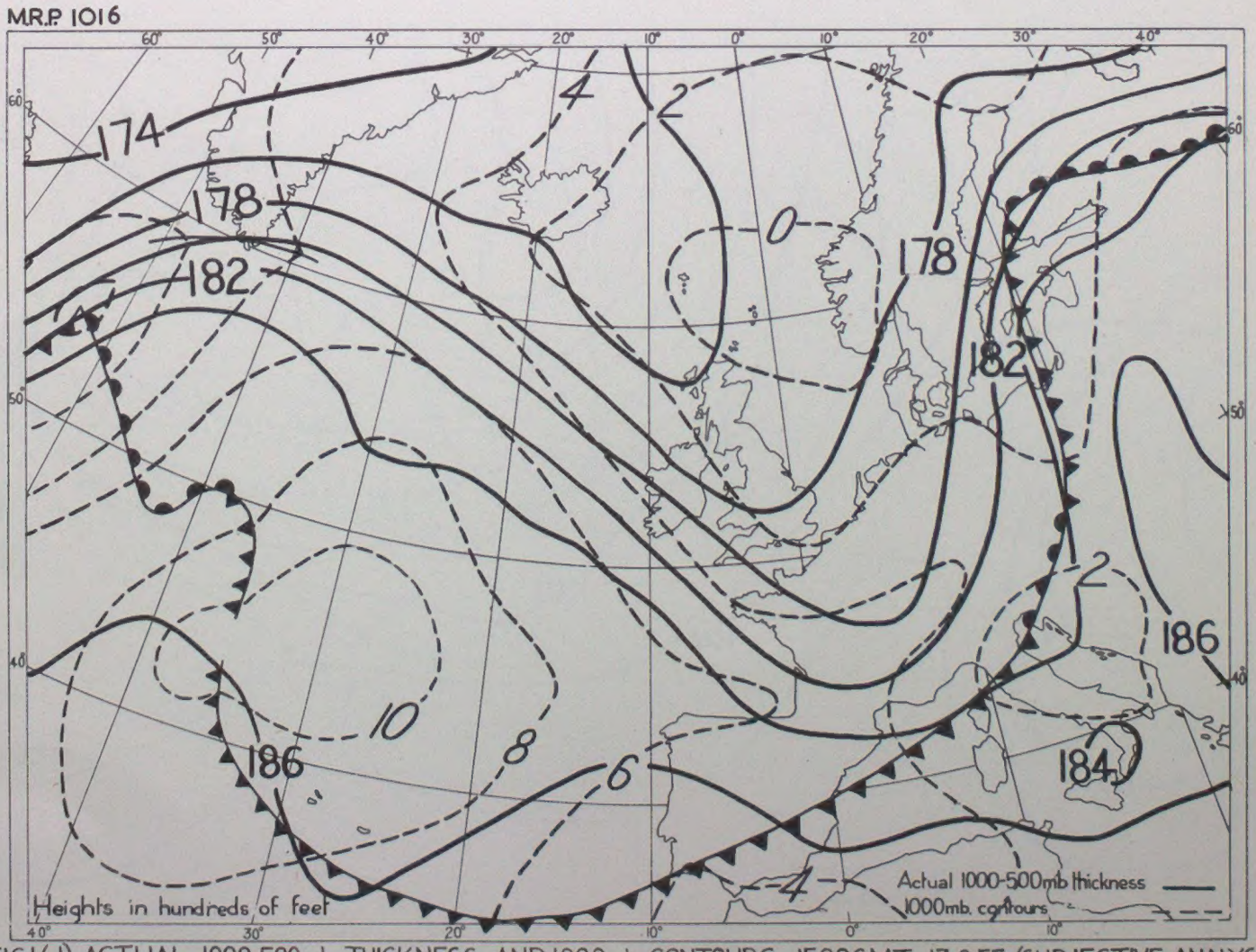

FIG. 1 (d) ACTUAL 1000-500 mb. THICKNESS AND 1000 mb CONTOURS 1500 G.M.T. 13:9:55 (SUBJECTIVE ANALYSIS)

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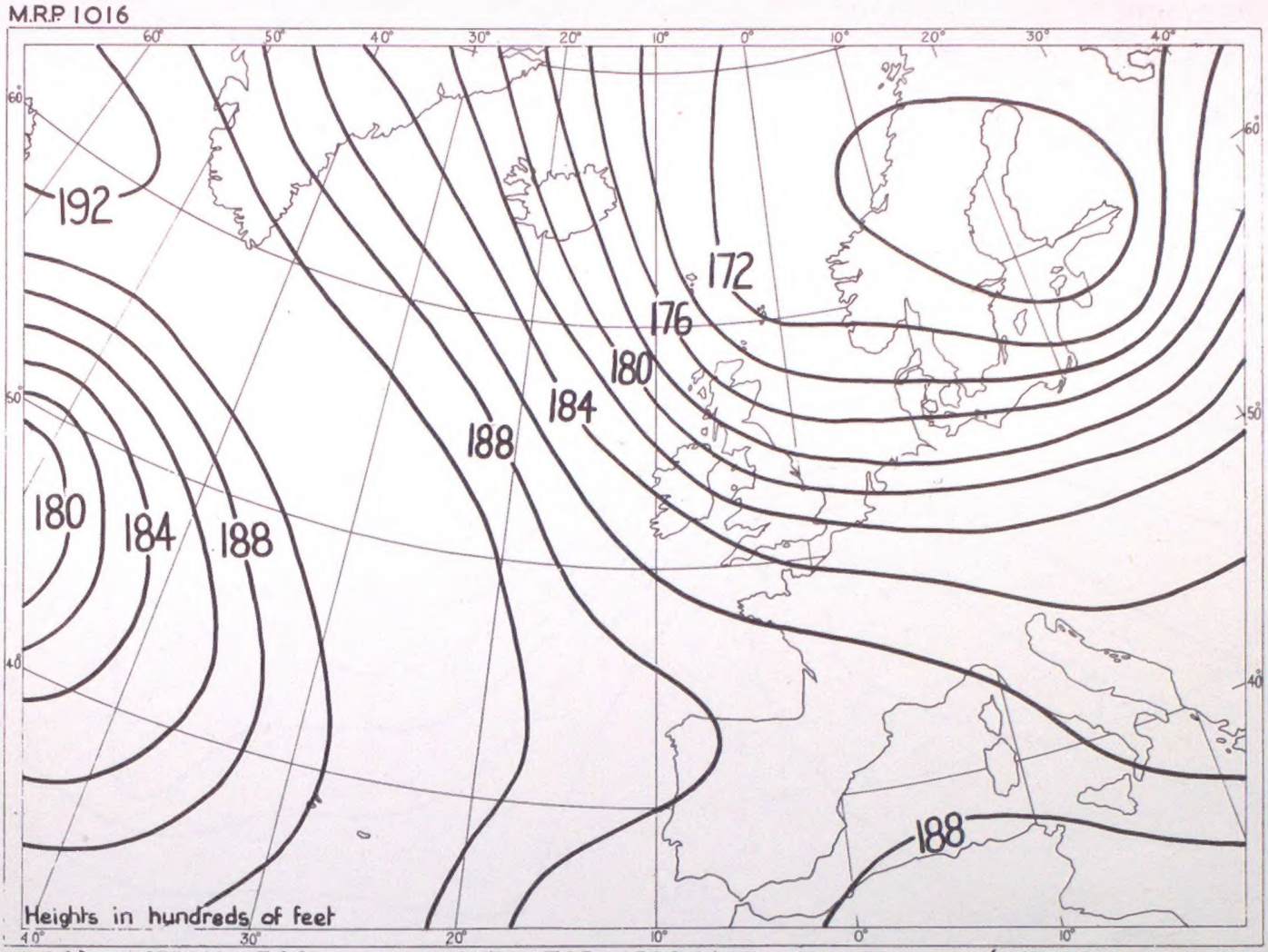

FIG 2(c) ACTUAL 500mb. CONTOURS FOR 1500 G.M.T. 16:10:55 (SUBJECTIVE ANALYSIS)

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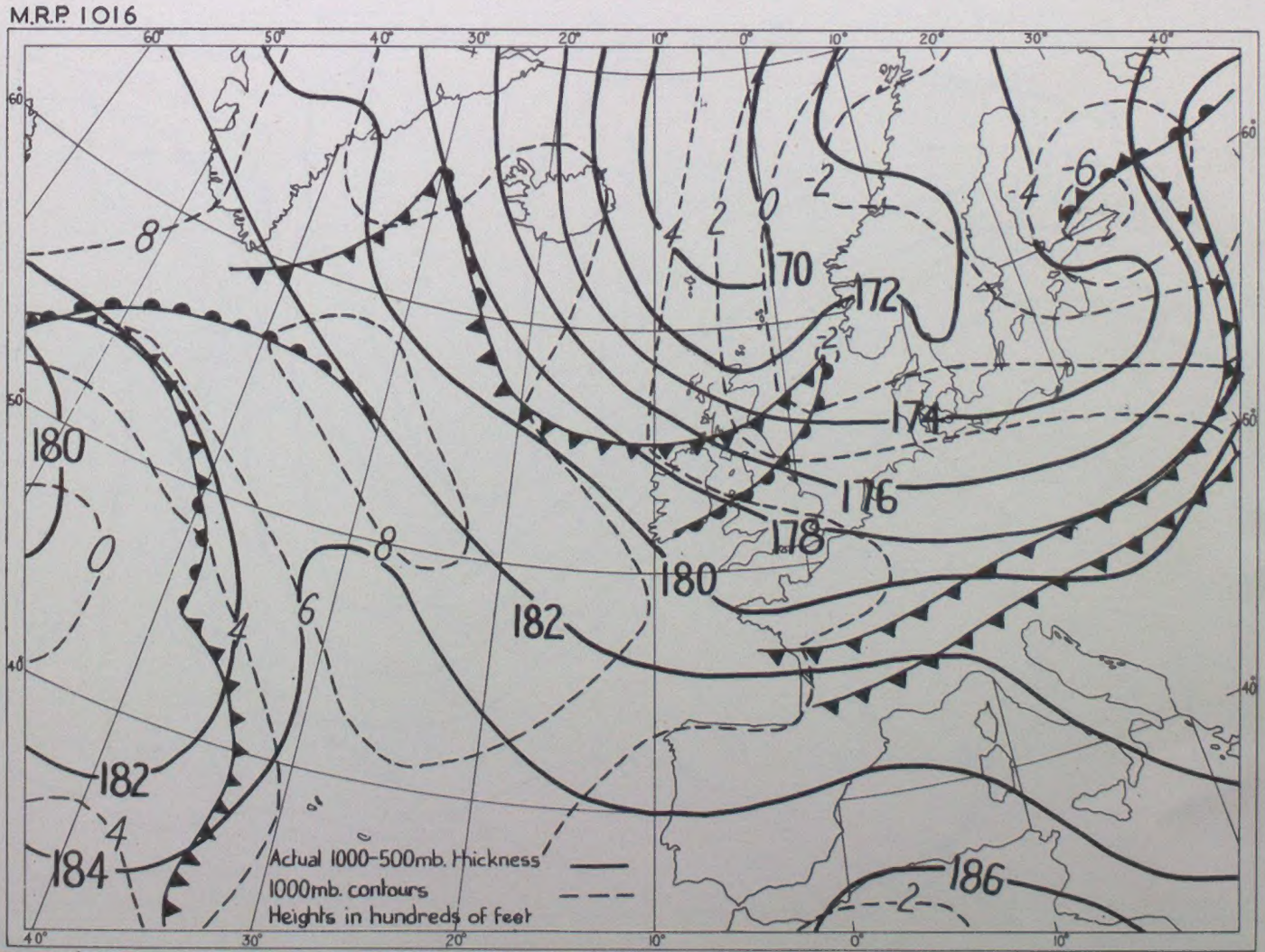

FIG. 2(d) ACTUAL 1000-500mb. THICKNESS AND 1000mb CONTOURS, 1500 G.M.T. 16:10:55 (SUBJECTIVE ANALYSIS)

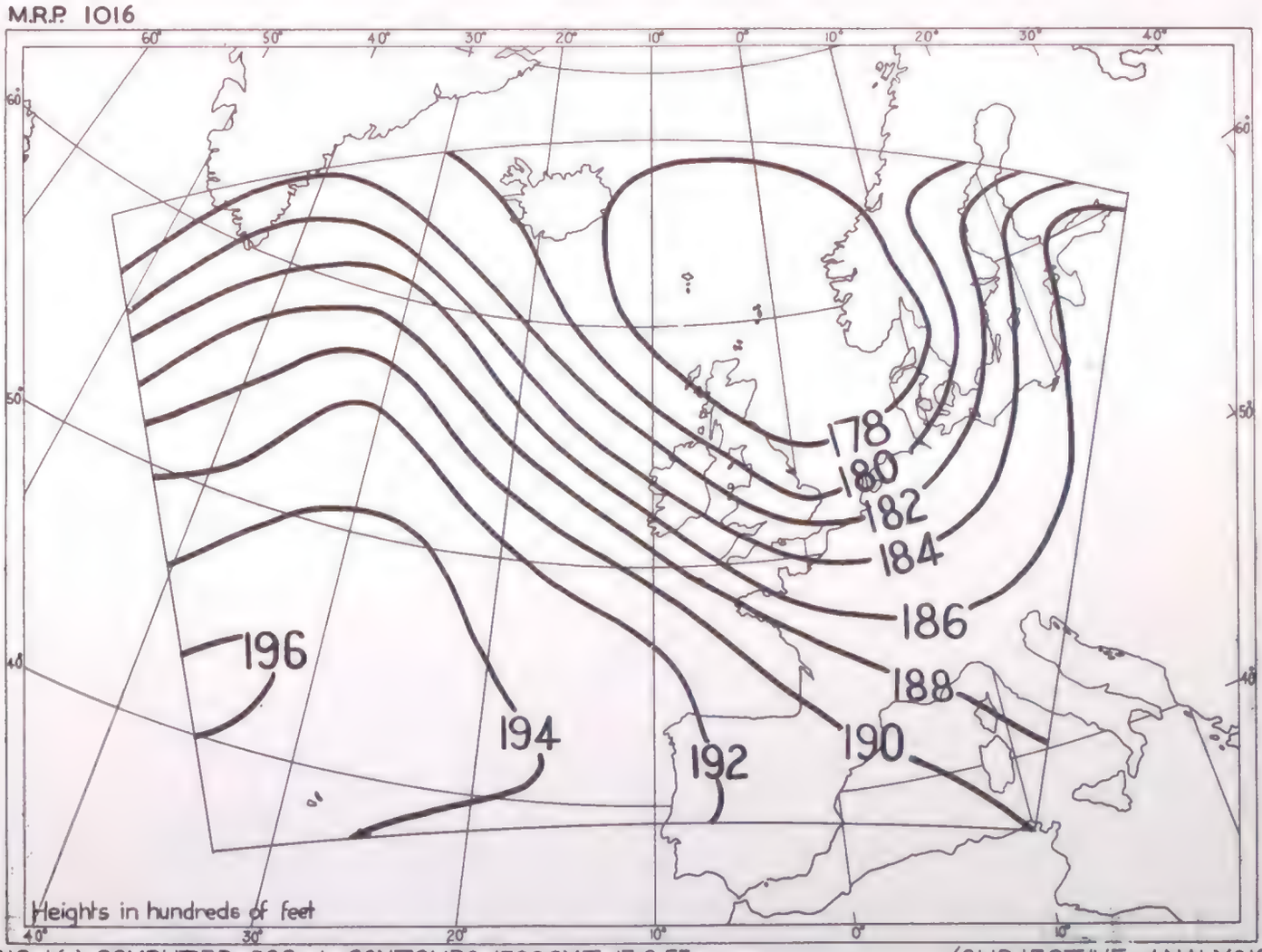

FIG. 1(e) COMPUTED 500 mb. CONTOURS, 1500 G.M.T. 13·9·55 (SUBJECTIVE ANALYSIS)

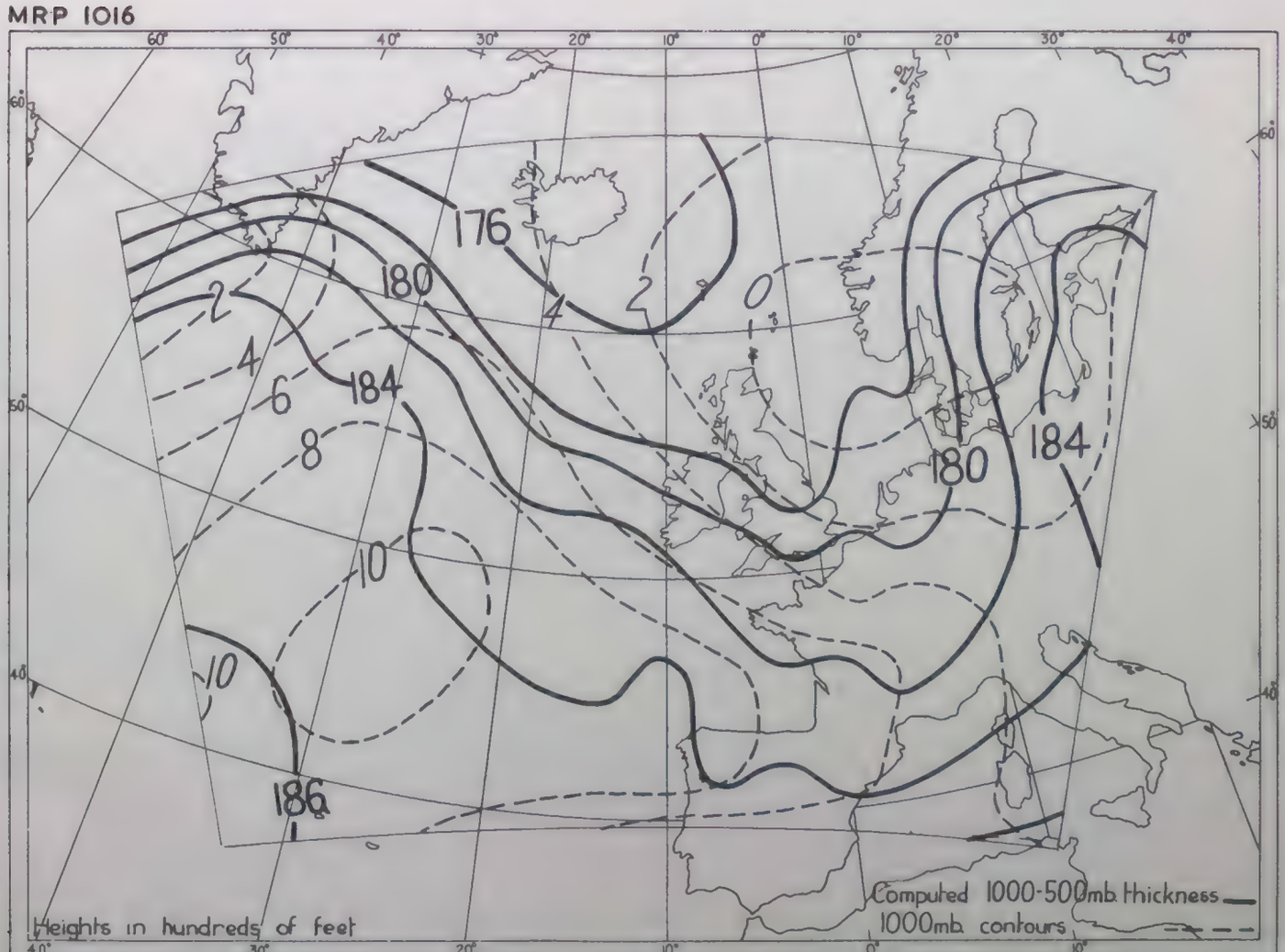

FIG. 1(f) COMPUTED 1000-500 mb. THICKNESS AND 1000 mb. CONTOURS 1500 G.M.T. 13·9·55 (SUBJECTIVE ANALYSIS)

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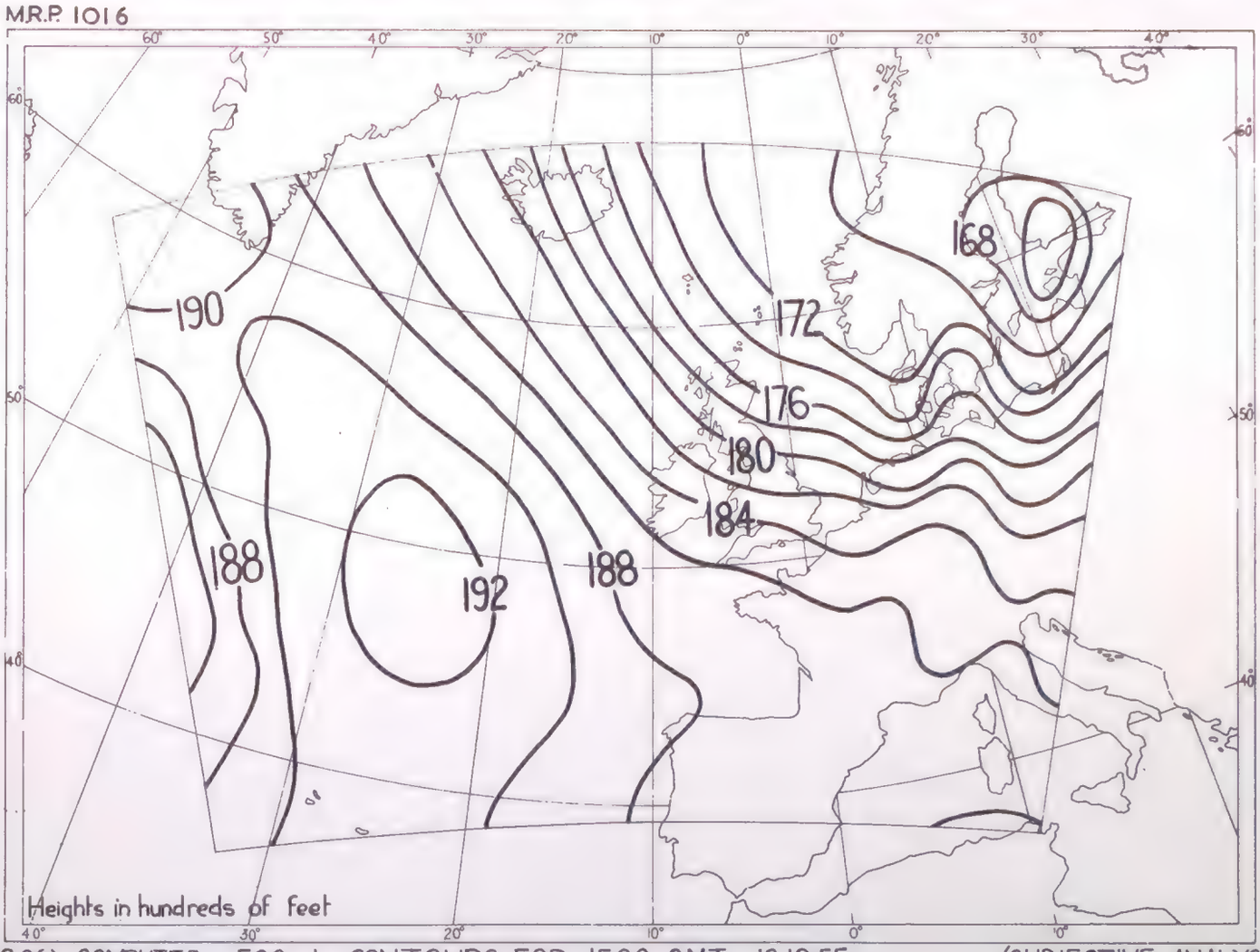

FIG.2(e) COMPUTED 500mb. CONTOURS FOR 1500 G.M.T. 16:10:55 (SUBJECTIVE ANALYSIS)

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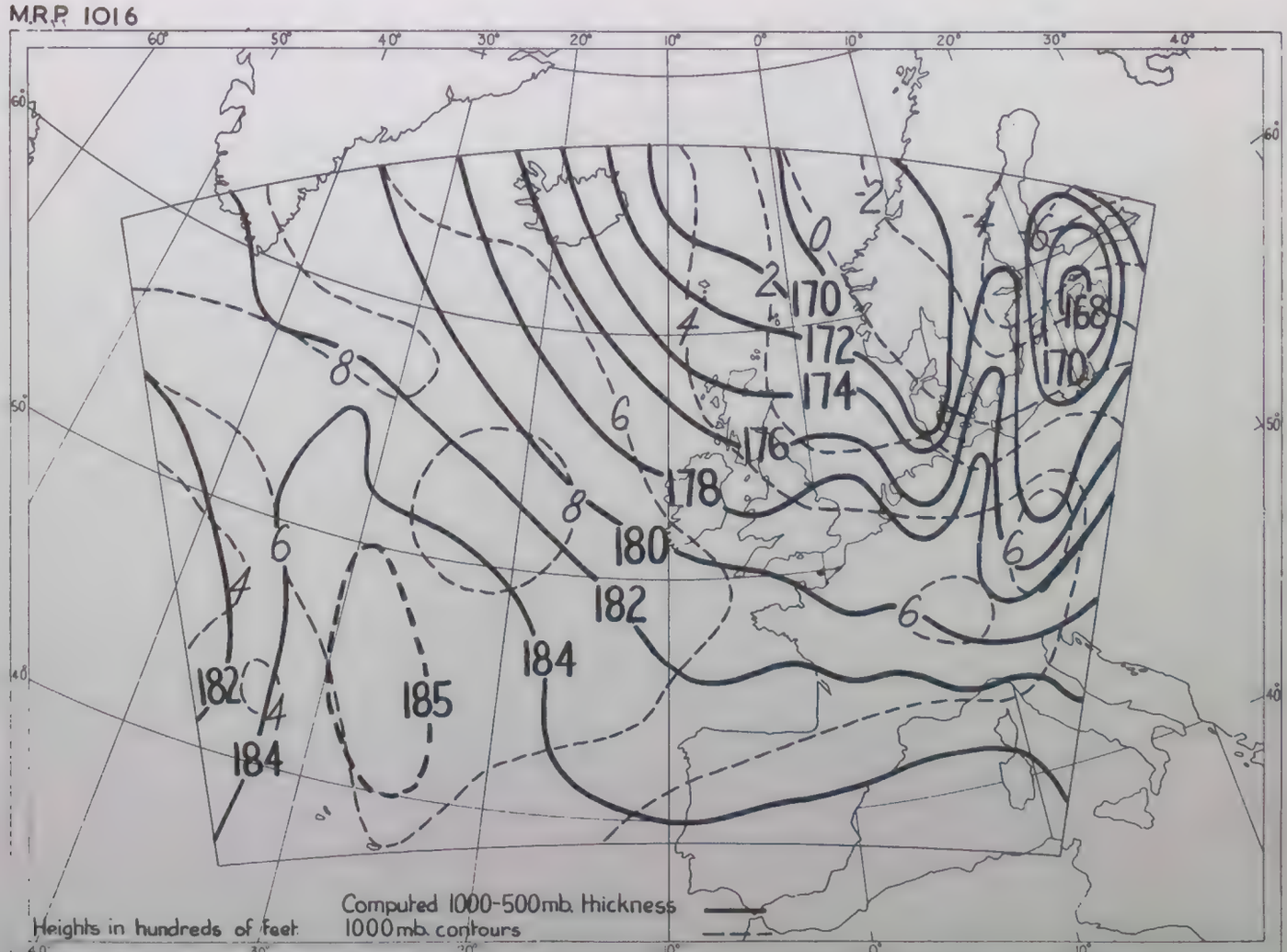

FIG2(f) COMPUTED 1000-500mb THICKNESS AND 1000mb. CONTOURS, 1500G.M.T. 16:10:55 (SUBJECTIVE ANALYSIS)

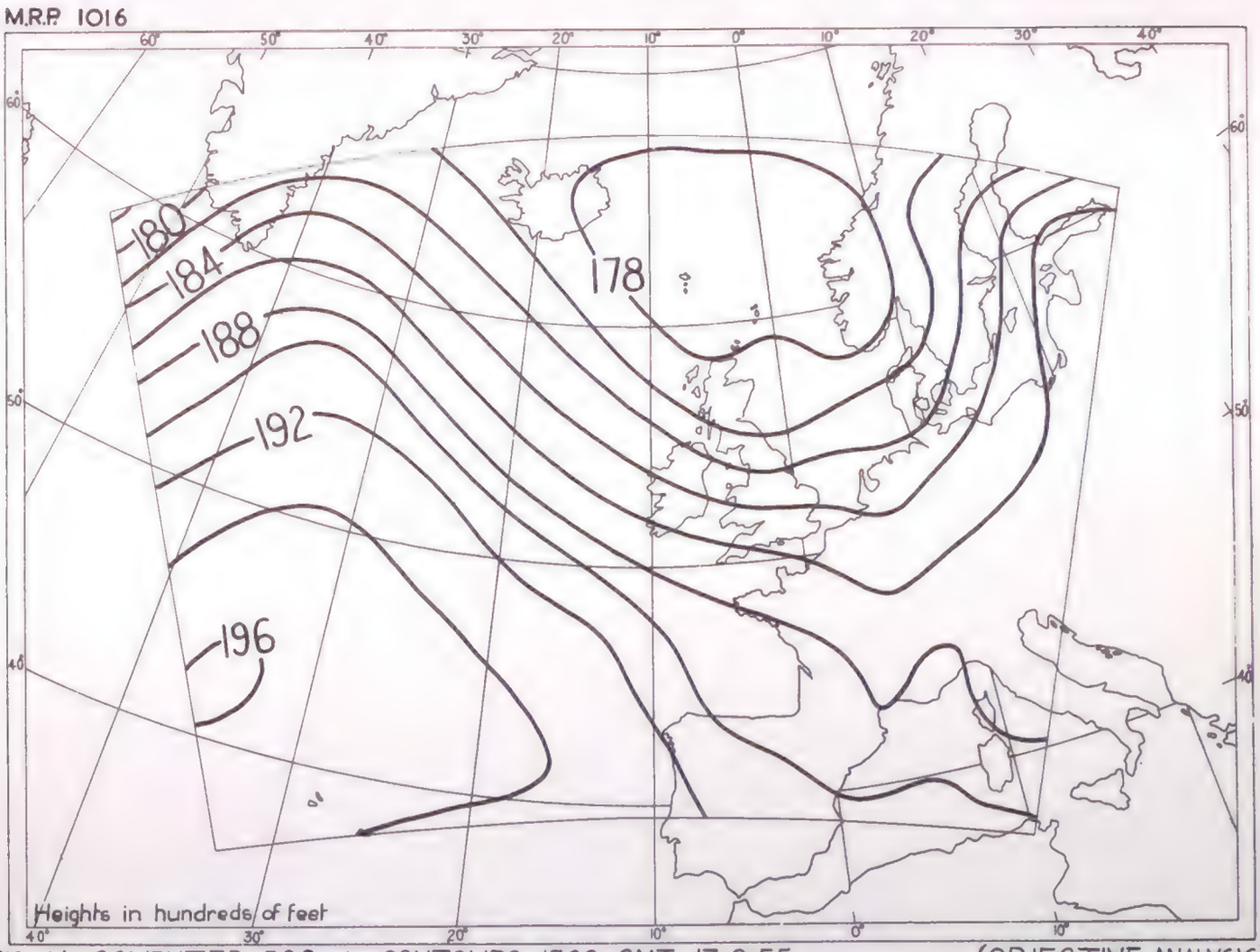

FIG.1(g) COMPUTED 500 mb. CONTOURS, 1500 G.M.T. 13:9:55 (OBJECTIVE ANALYSIS)

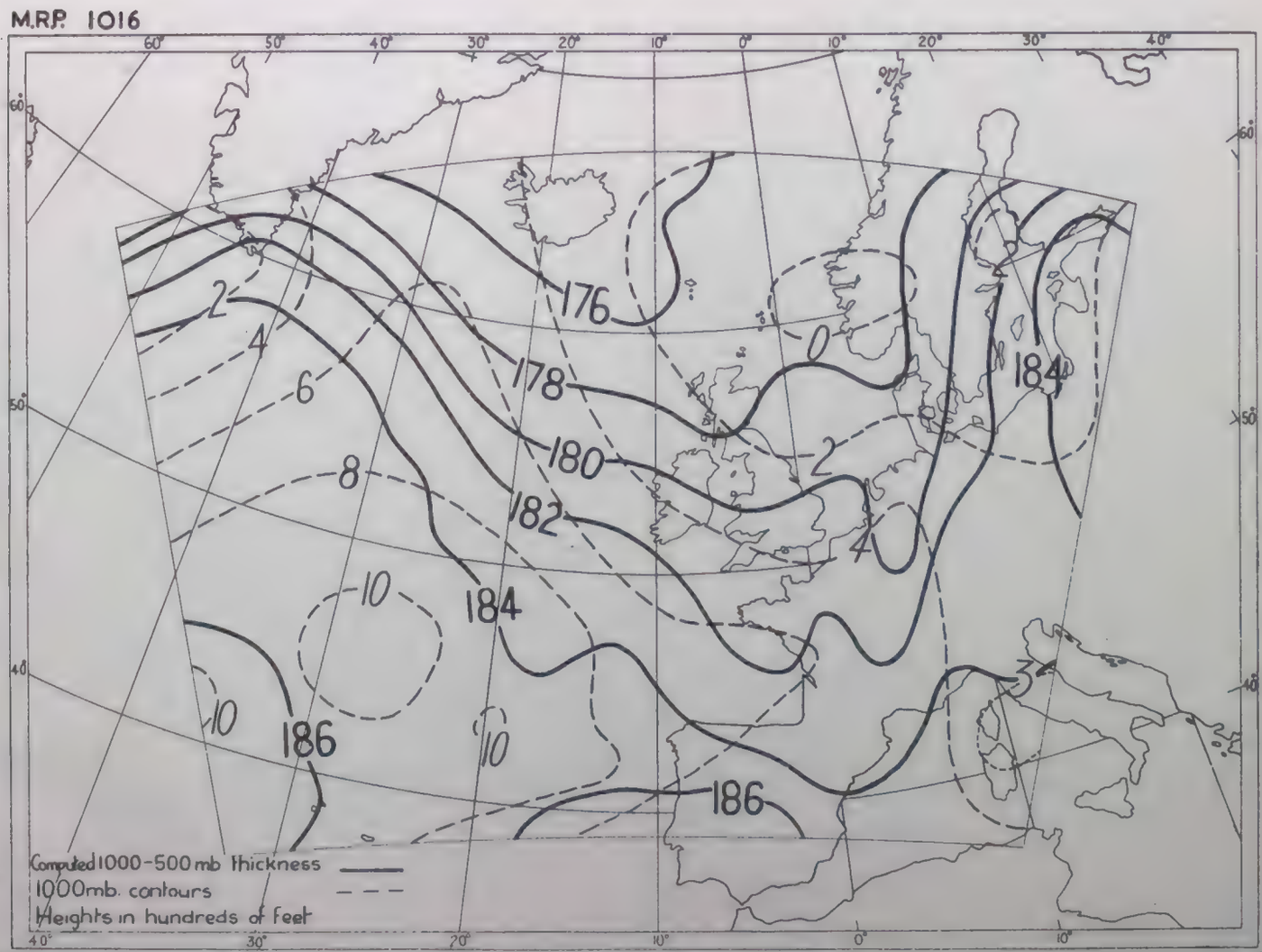

FIG. 1(h) COMPUTED 1000-500 mb. THICKNESS AND 1000 mb. CONTOURS, 1500 G.M.T. 13:9:55 (OBJECTIVE ANALYSIS)

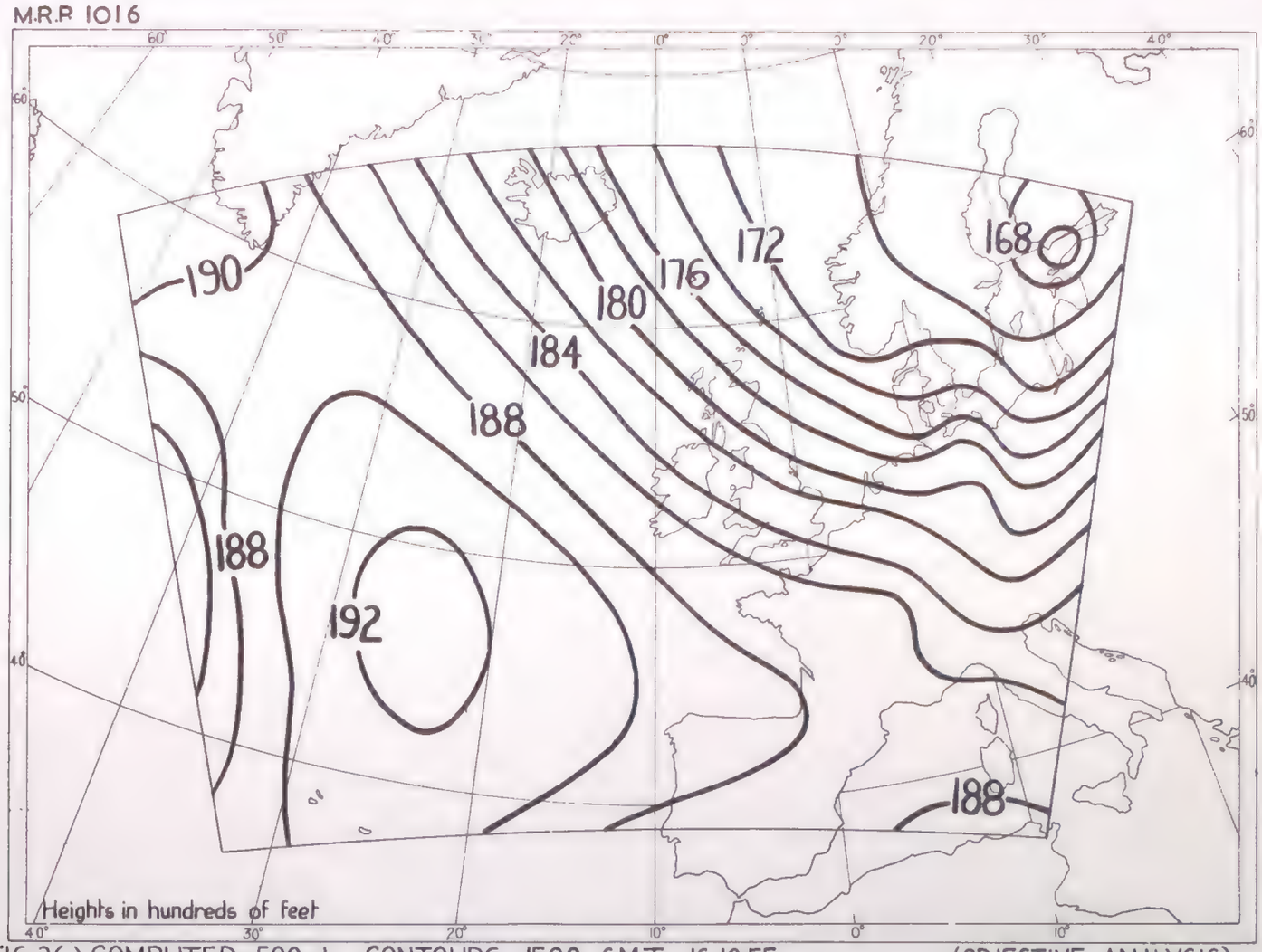

FIG 2(g) COMPUTED 500mb CONTOURS, 1500 G.M.T. 16:10:55 (OBJECTIVE ANALYSIS)

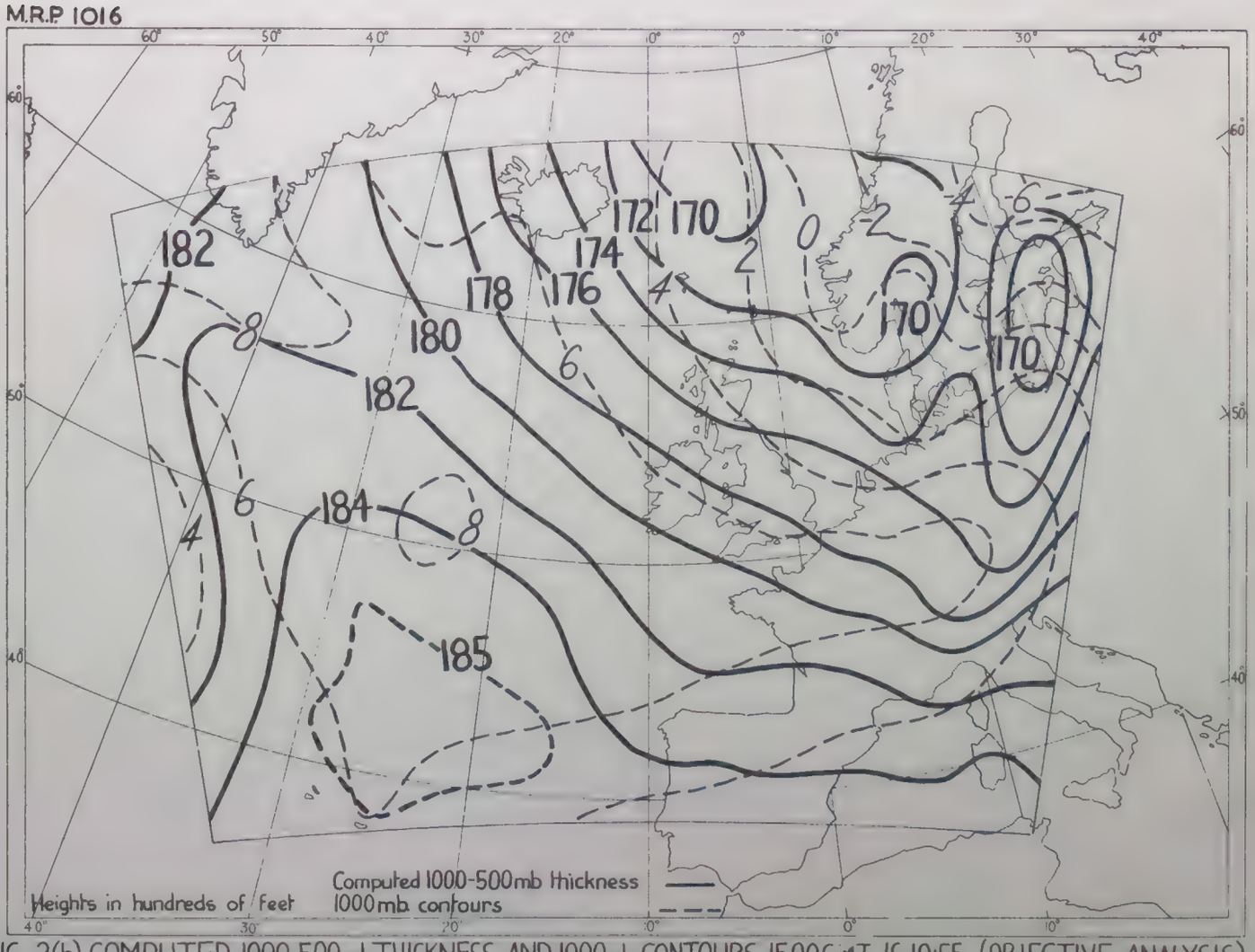

FIG. 2(h) COMPUTED 1000-500mb THICKNESS AND 1000mb. CONTOURS, 1500 G.M.T. 16:10:55 (OBJECTIVE ANALYSIS)

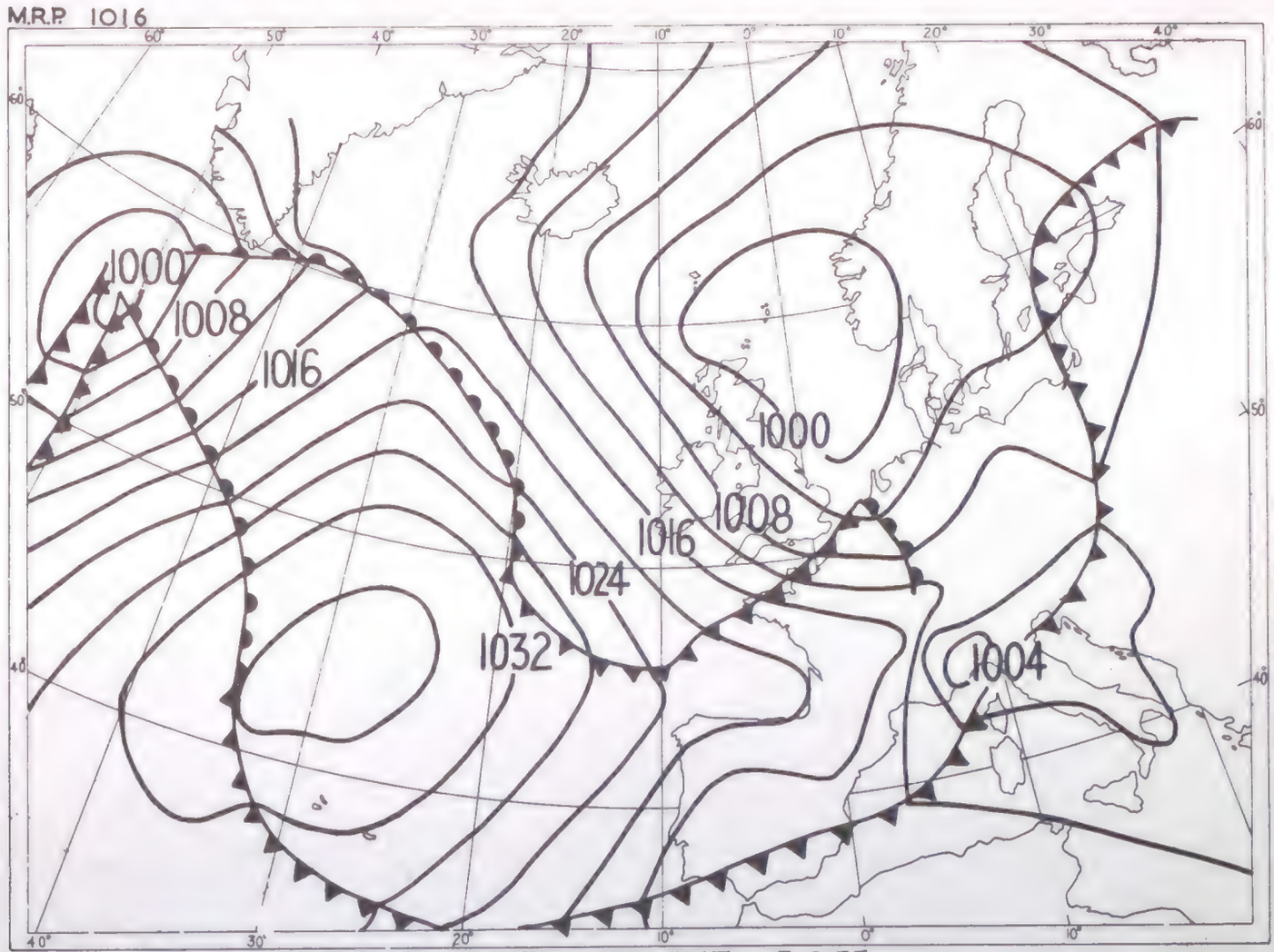

FIG.1(i) ACTUAL SURFACE CHART 1800 G.M.T. 13:9:55

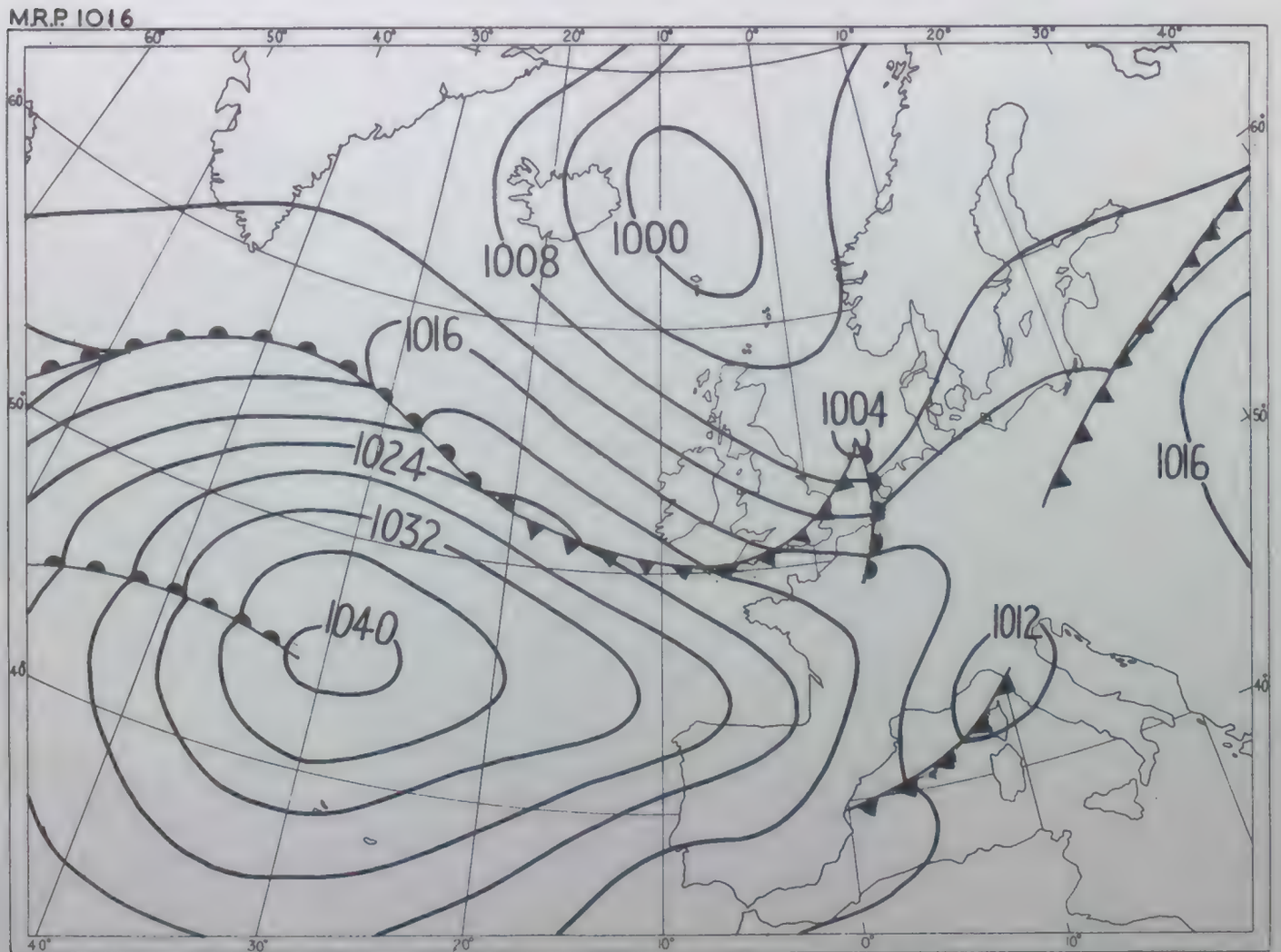

FIG. 1(j) CONVENTIONAL SURFACE FORECAST 1800 G.M.T. 13:9:55

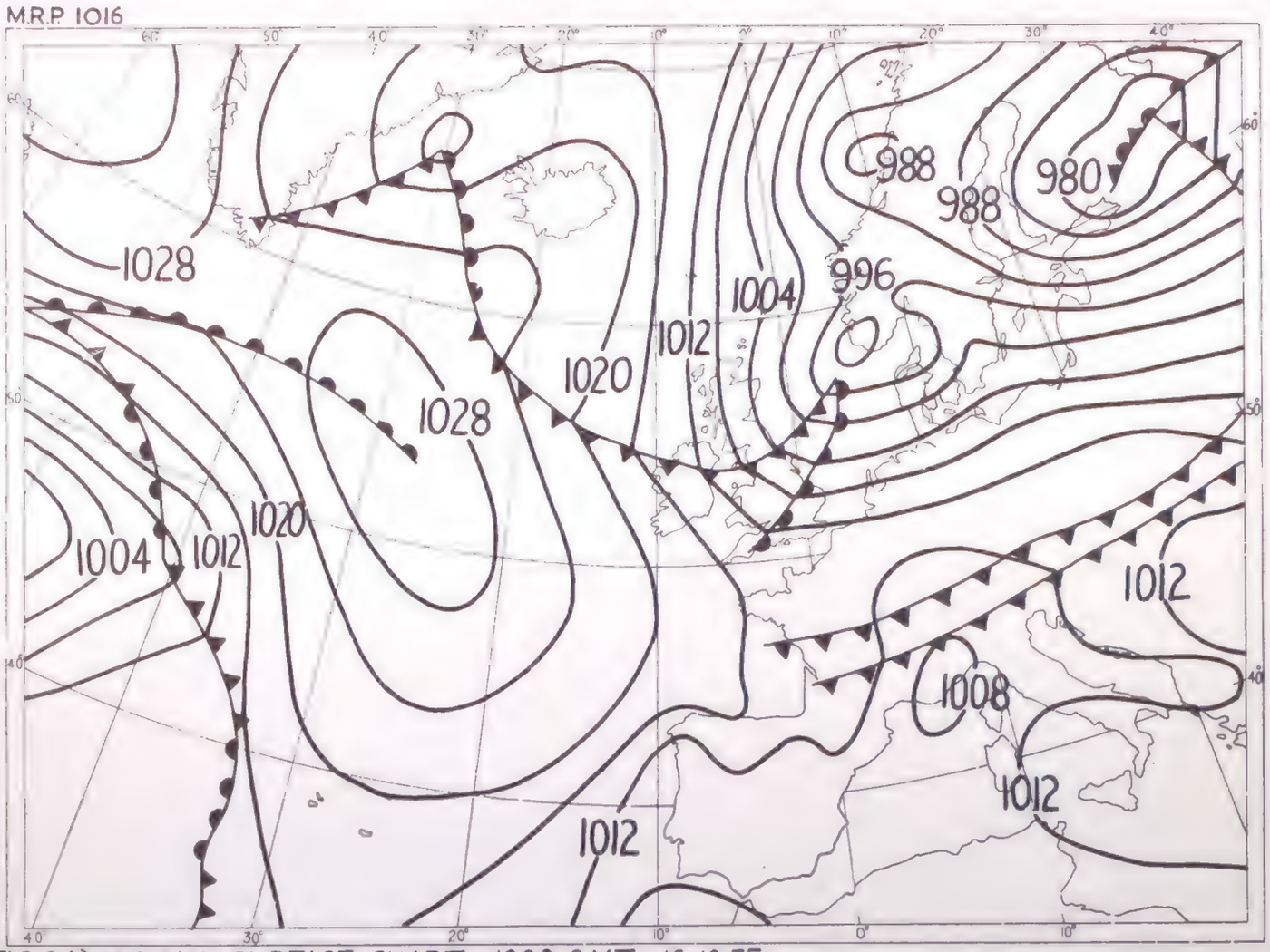

FIG. 2(i) ACTUAL SURFACE CHART, 1800 G.M.T. 16:10:55

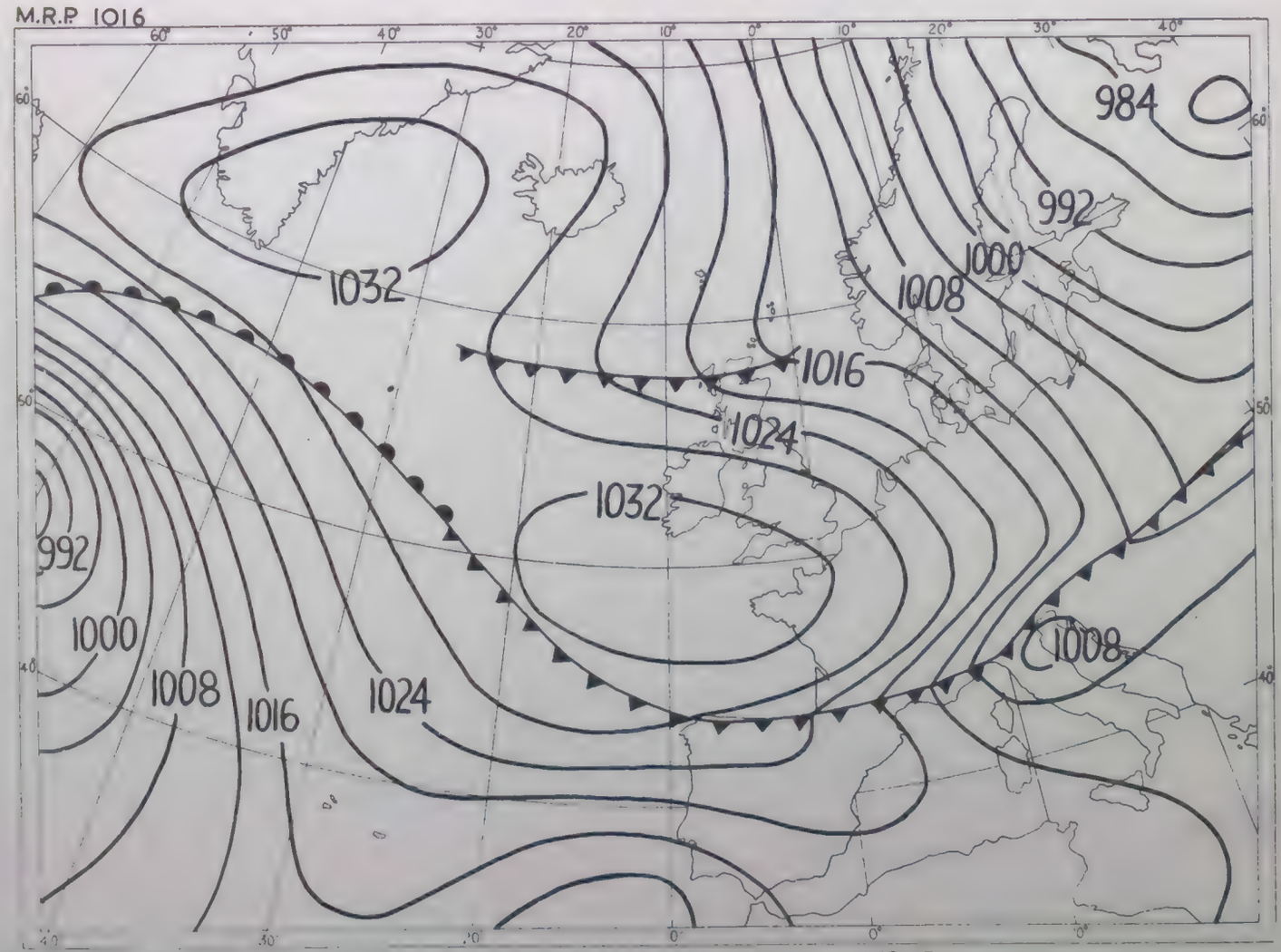

FIG. 2(j) CONVENTIONAL SURFACE FORECAST, 1800 G.M.T. 16:10:55

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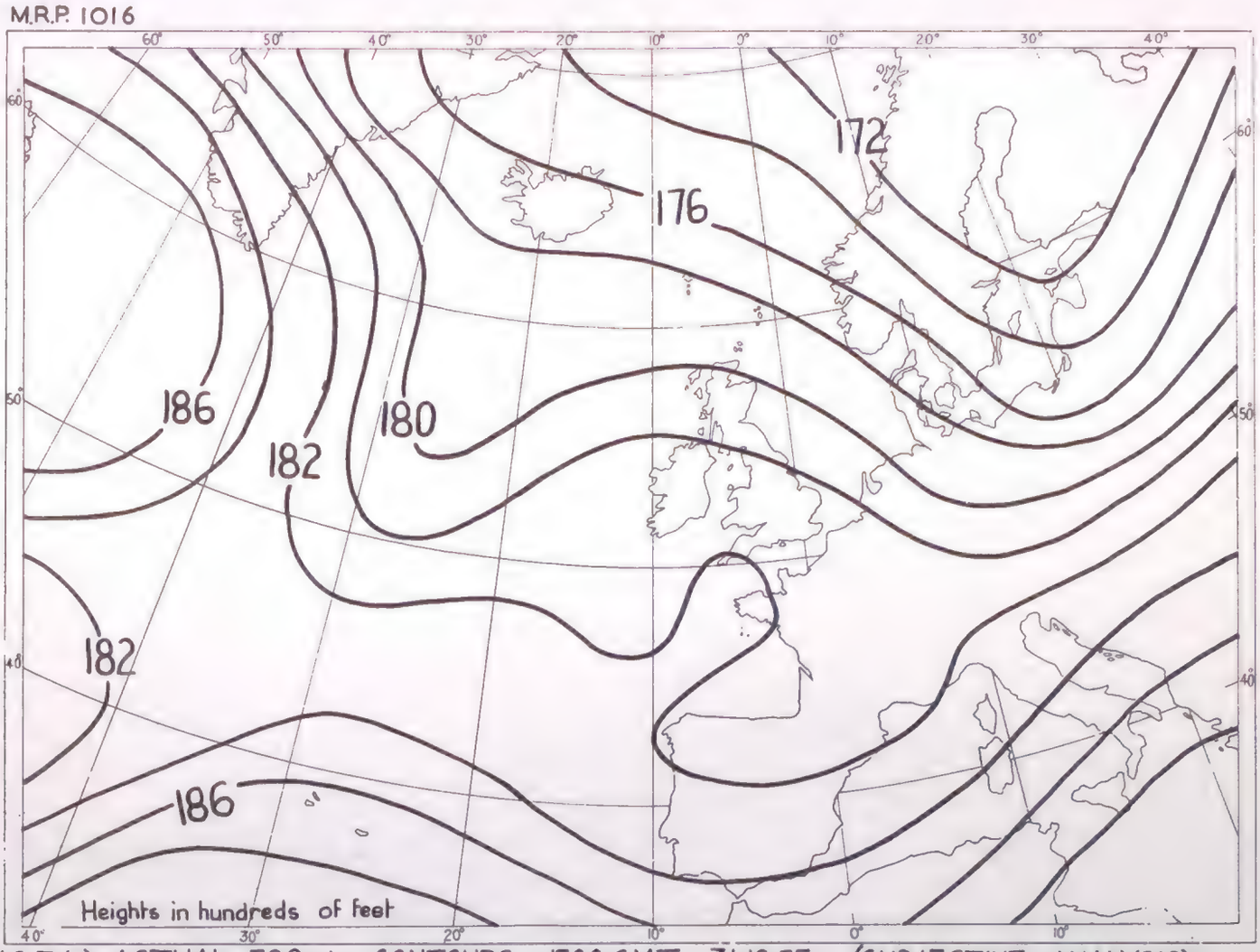

FIG. 3(a) ACTUAL 500mb. CONTOURS, 1500 G.M.T. 31:10:55 (SUBJECTIVE ANALYSIS)

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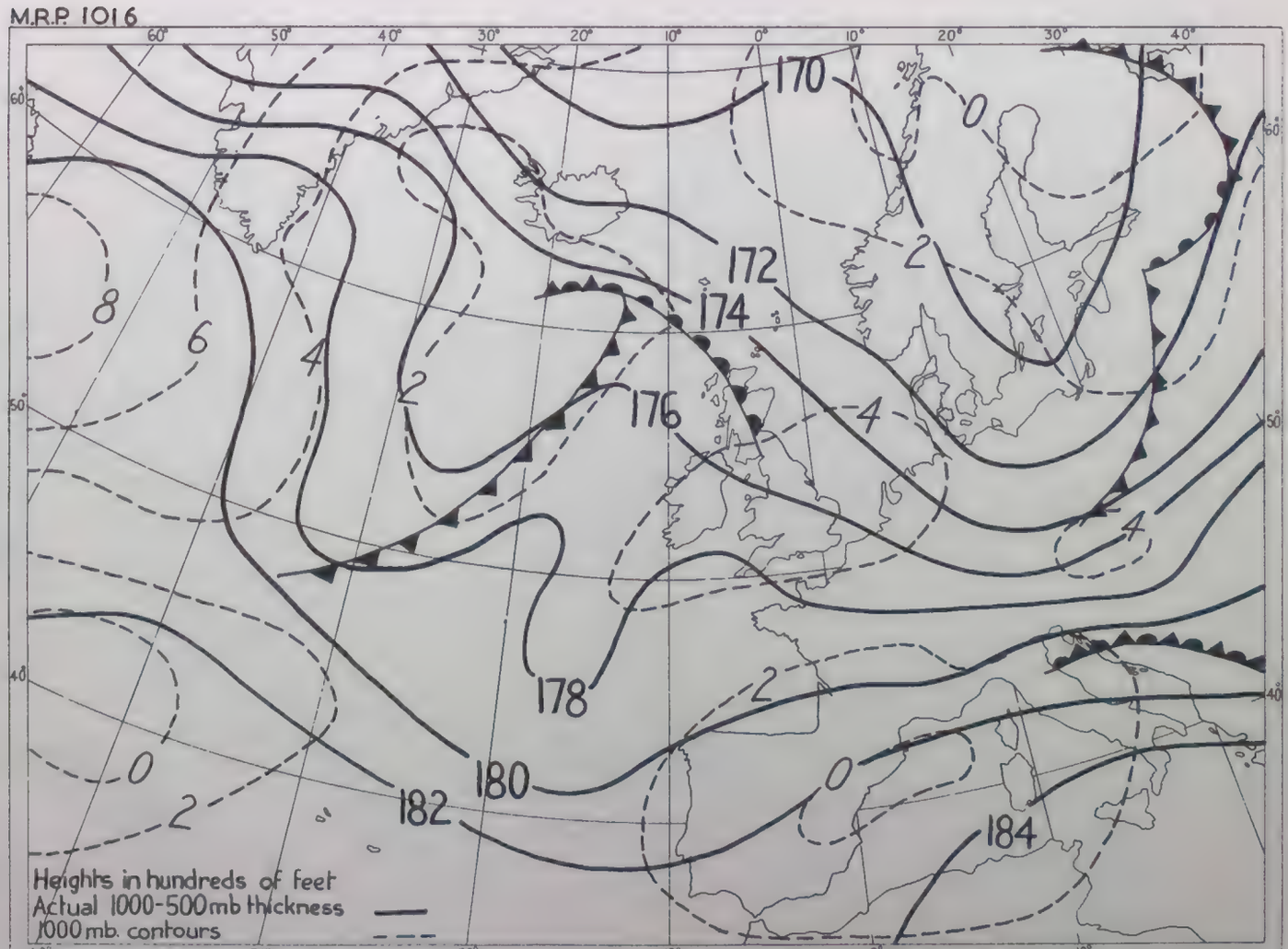

FIG. 3(b) ACTUAL 1000-500mb THICKNESS AND 1000mb CONTOURS, 1500 G.M.T. 31:10:55 (SUBJECTIVE ANALYSIS)

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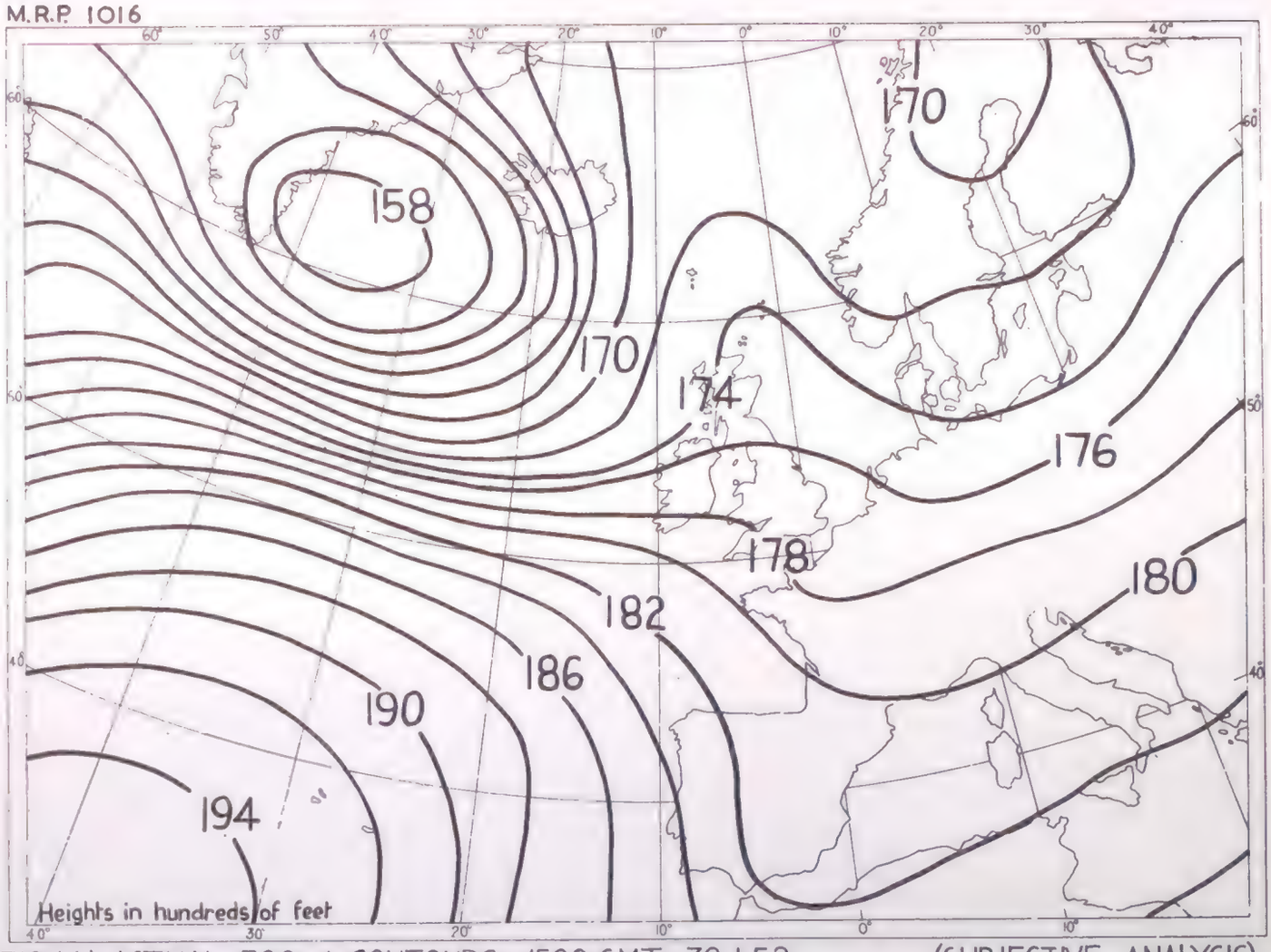

FIG.4(a) ACTUAL 500mb. CONTOURS, 1500 G.M.T. 30:1:52 (SUBJECTIVE ANALYSIS)

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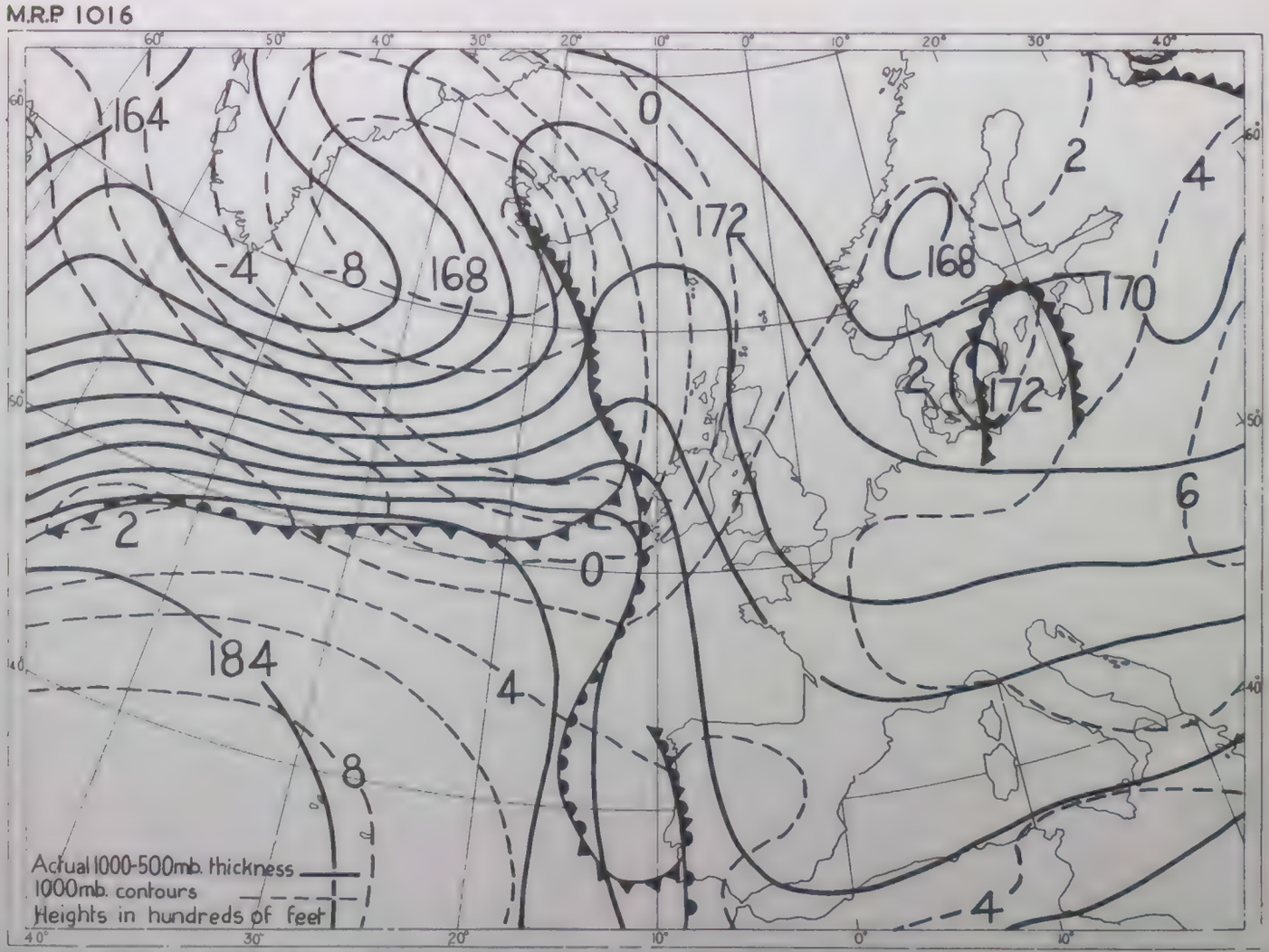

FIG. 4 (b) ACTUAL 1000-500mb. THICKNESS AND 1000mb. CONTOURS, 1500 G.M.T. 30:1:52 (SUBJECTIVE ANALYSIS)

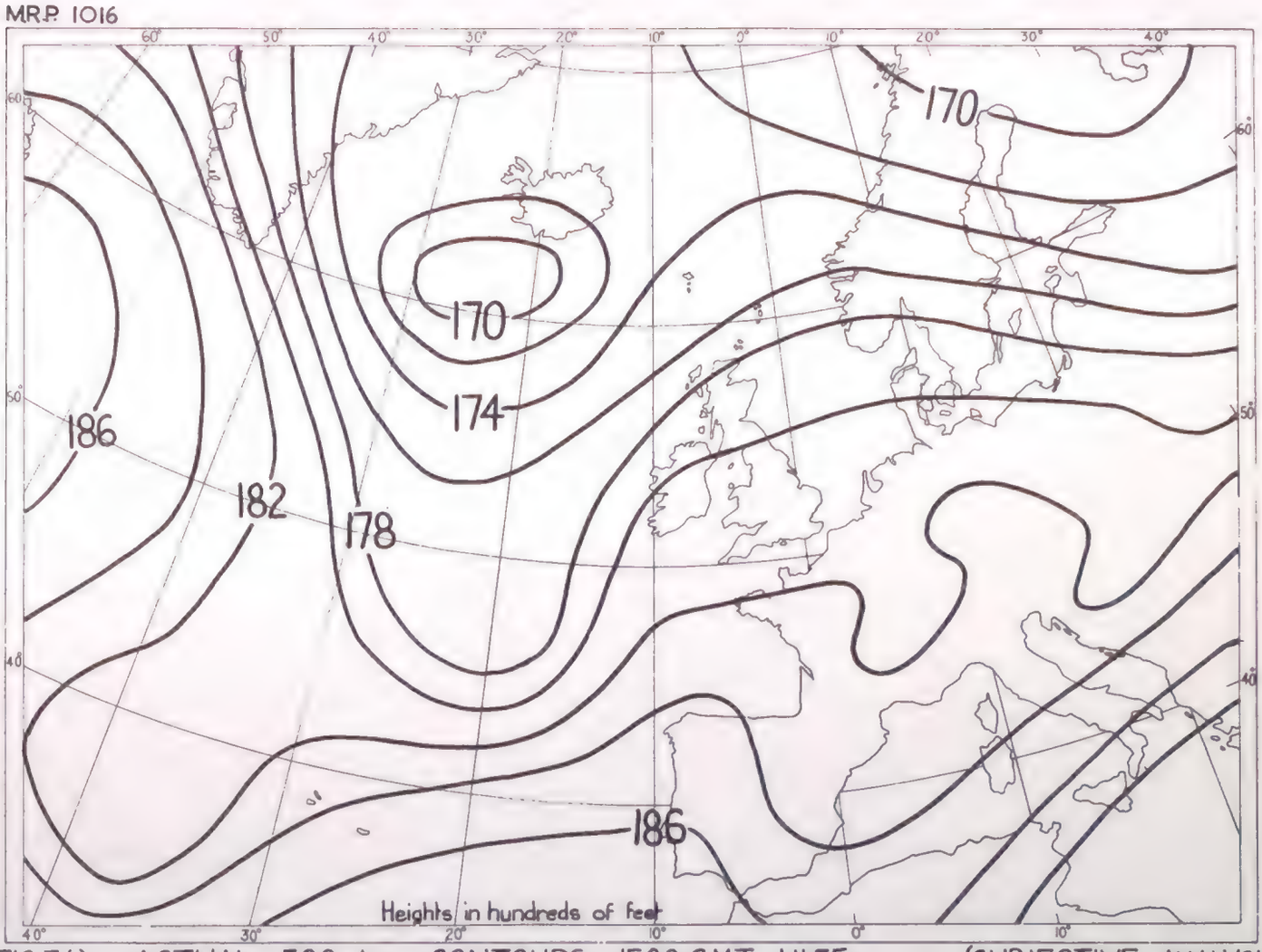

FIG. 3(c) ACTUAL 500mb. CONTOURS, 1500 G.M.T. 1:11:55 (SUBJECTIVE ANALYSIS)

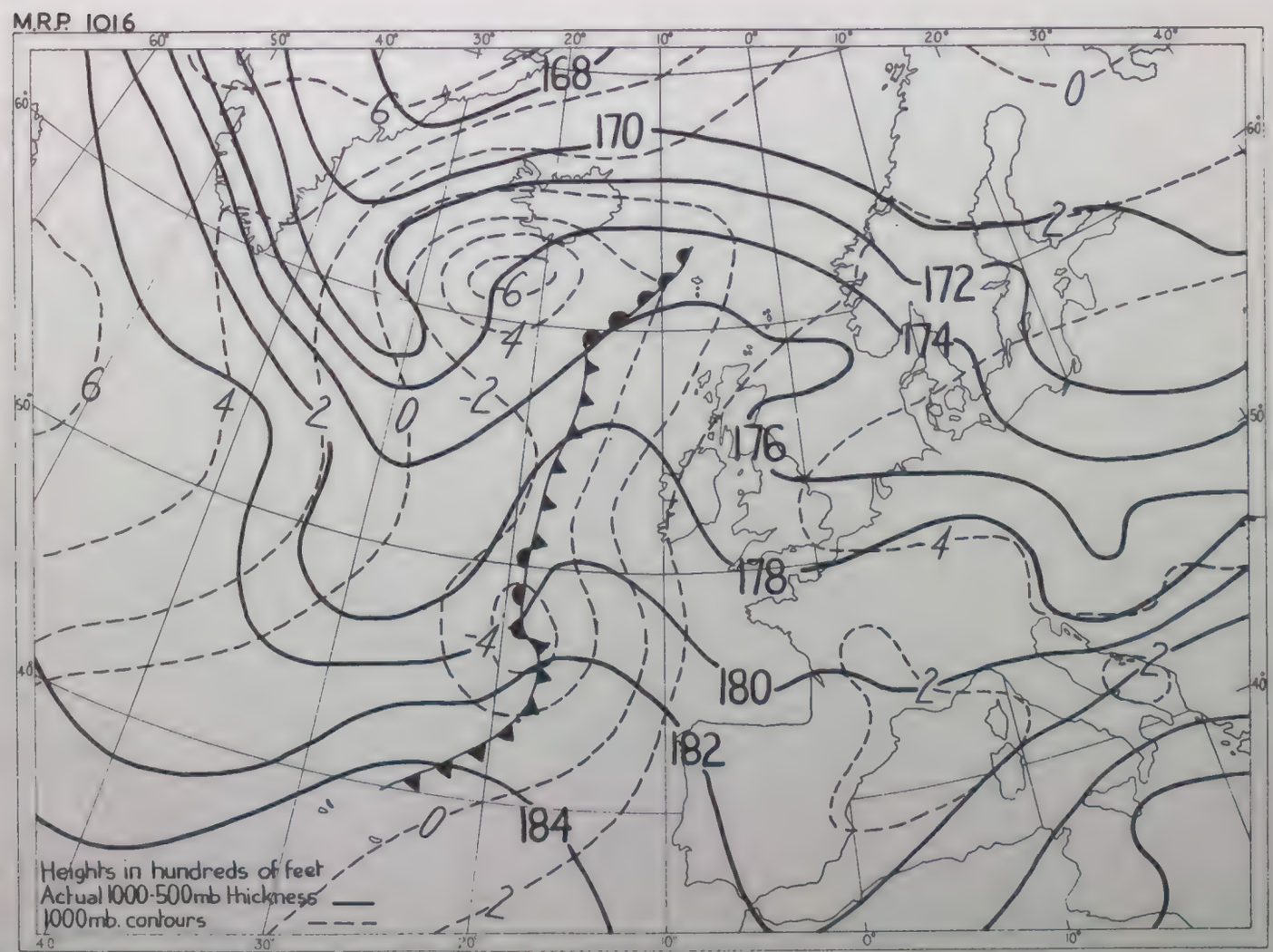

FIG. 3 (d) ACTUAL 1000-500mb. THICKNESS AND 1000mb. CONTOURS, 1500 G.M.T. 1:11:55

M.R.P. 1016

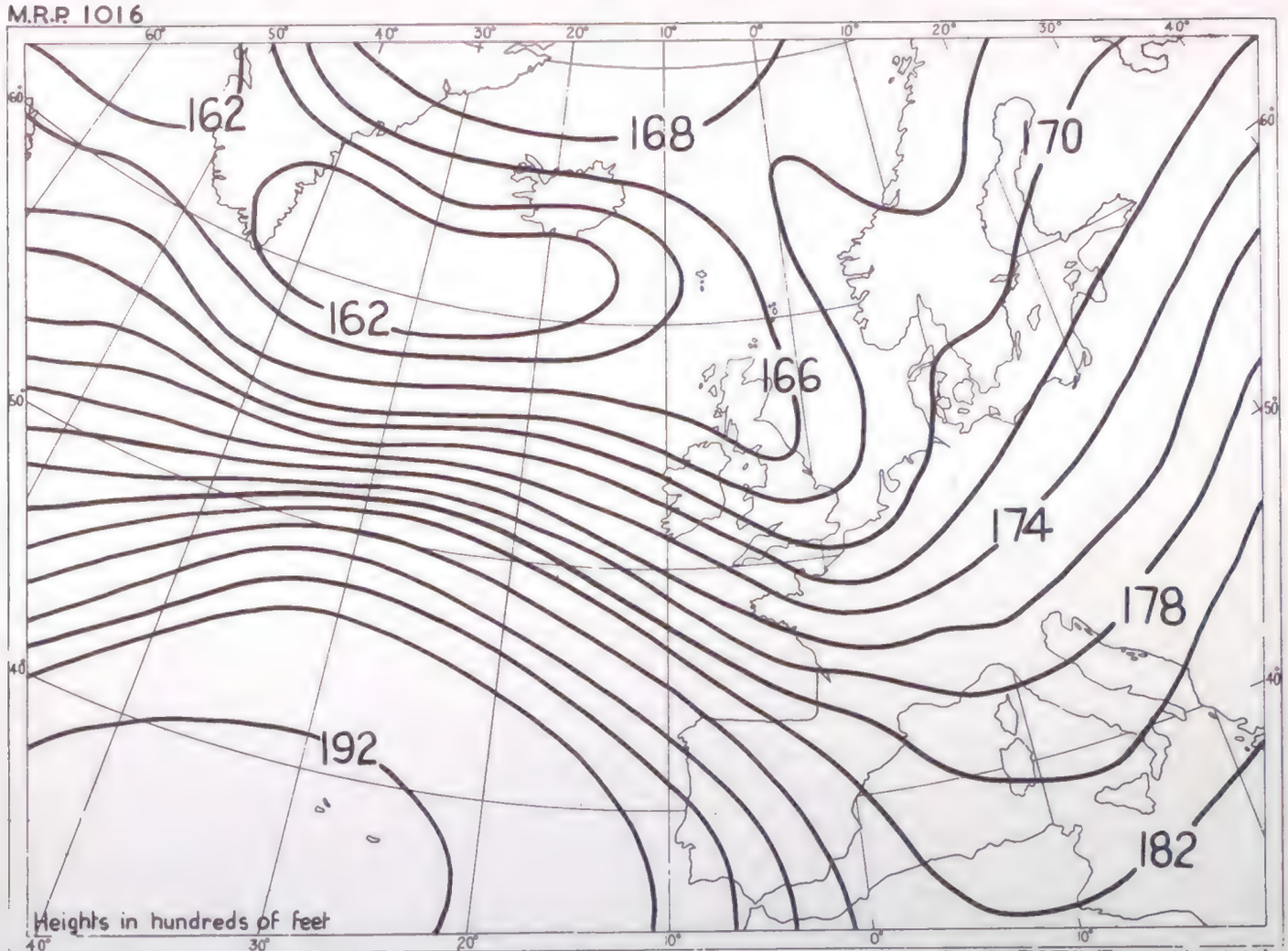

FIG.4(c) ACTUAL 500mb. CONTOURS 1500 G.M.T. 31:1:52 (SUBJECTIVE ANALYSIS)

M.R.P. 1016

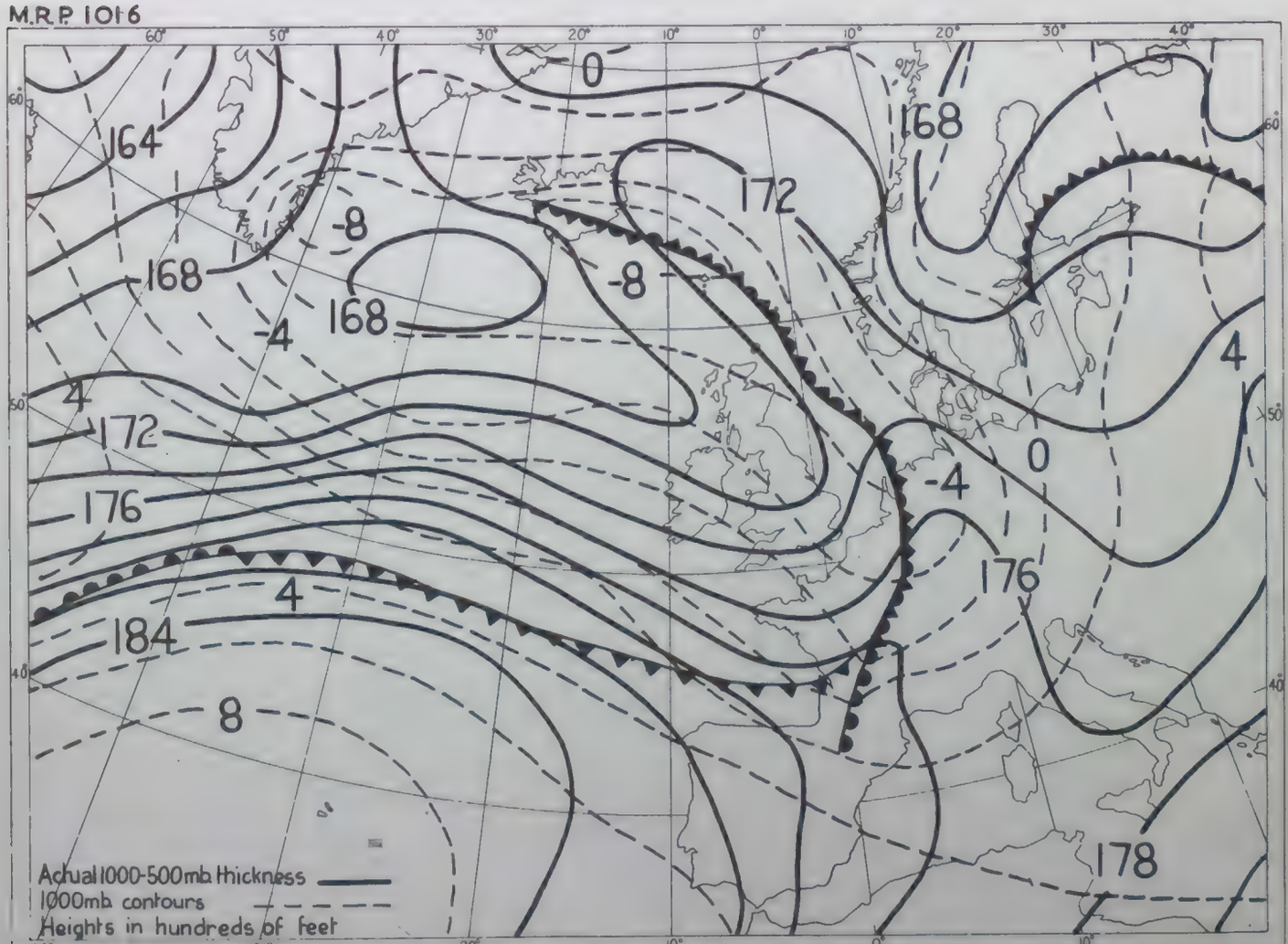

FIG.4(d) ACTUAL 1000-500mb. THICKNESS AND 1000mb. CONTOURS 1500G.M.T. 31:1:52 (SUBJECTIVE ANALYSIS)

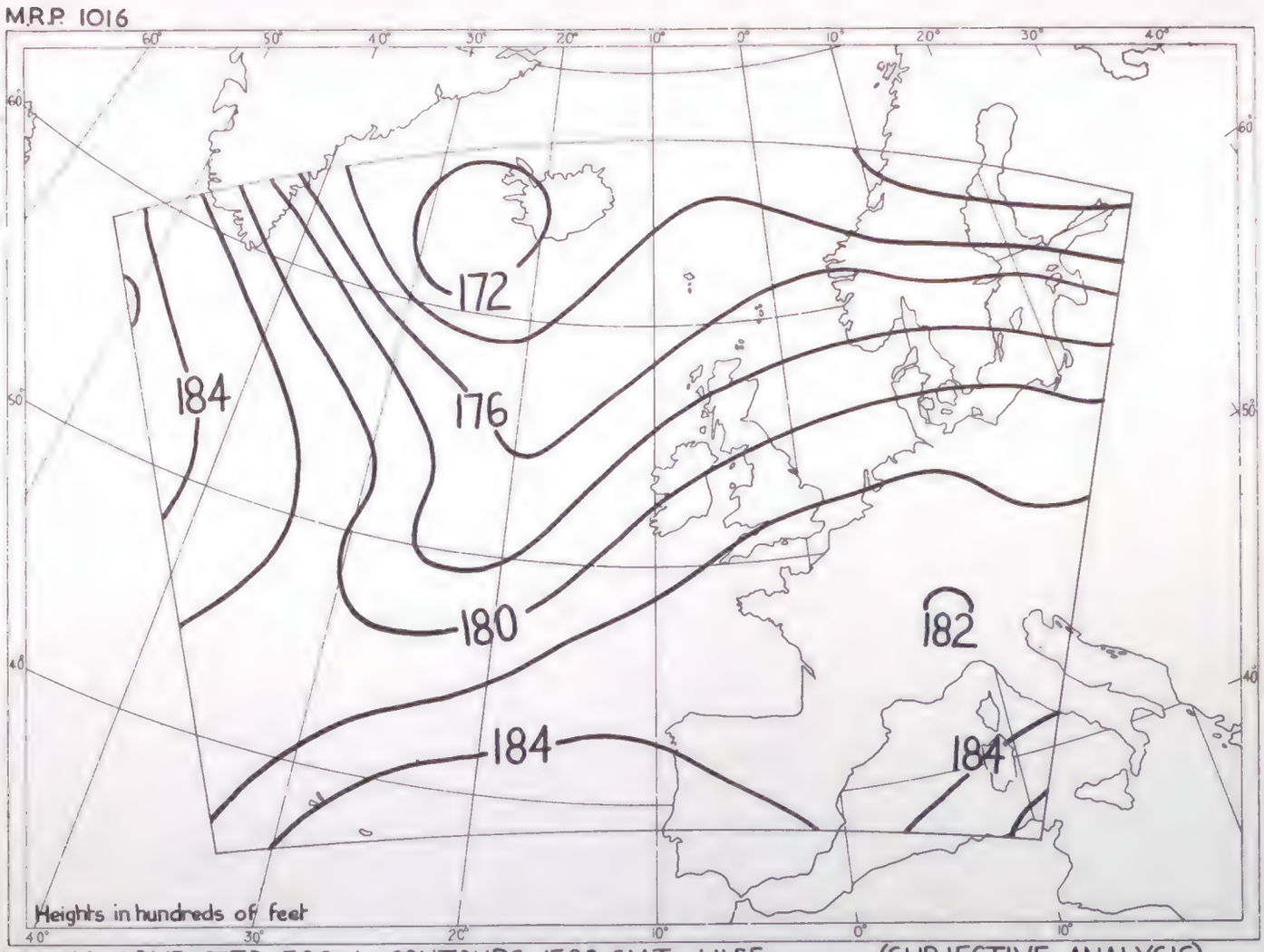

FIG. 3(e) COMPUTED 500mb. CONTOURS 1500 G.M.T. 1:11:55 (SUBJECTIVE ANALYSIS)

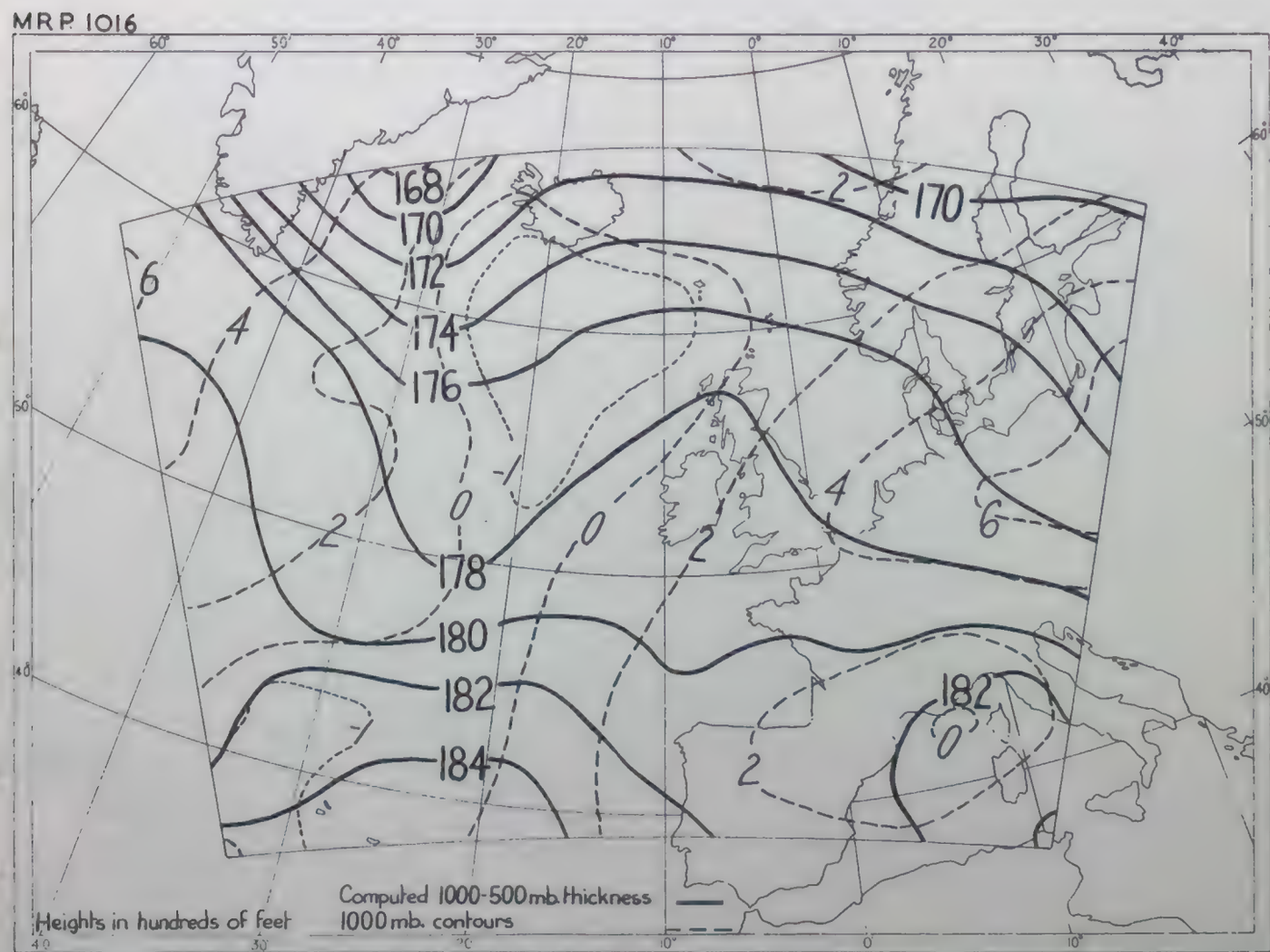

FIG. 3(f) COMPUTED 1000-500mb. THICKNESS AND 1000mb. CONTOURS 1500 G.M.T. 1:11:55 (SUBJECTIVE ANALYSIS)

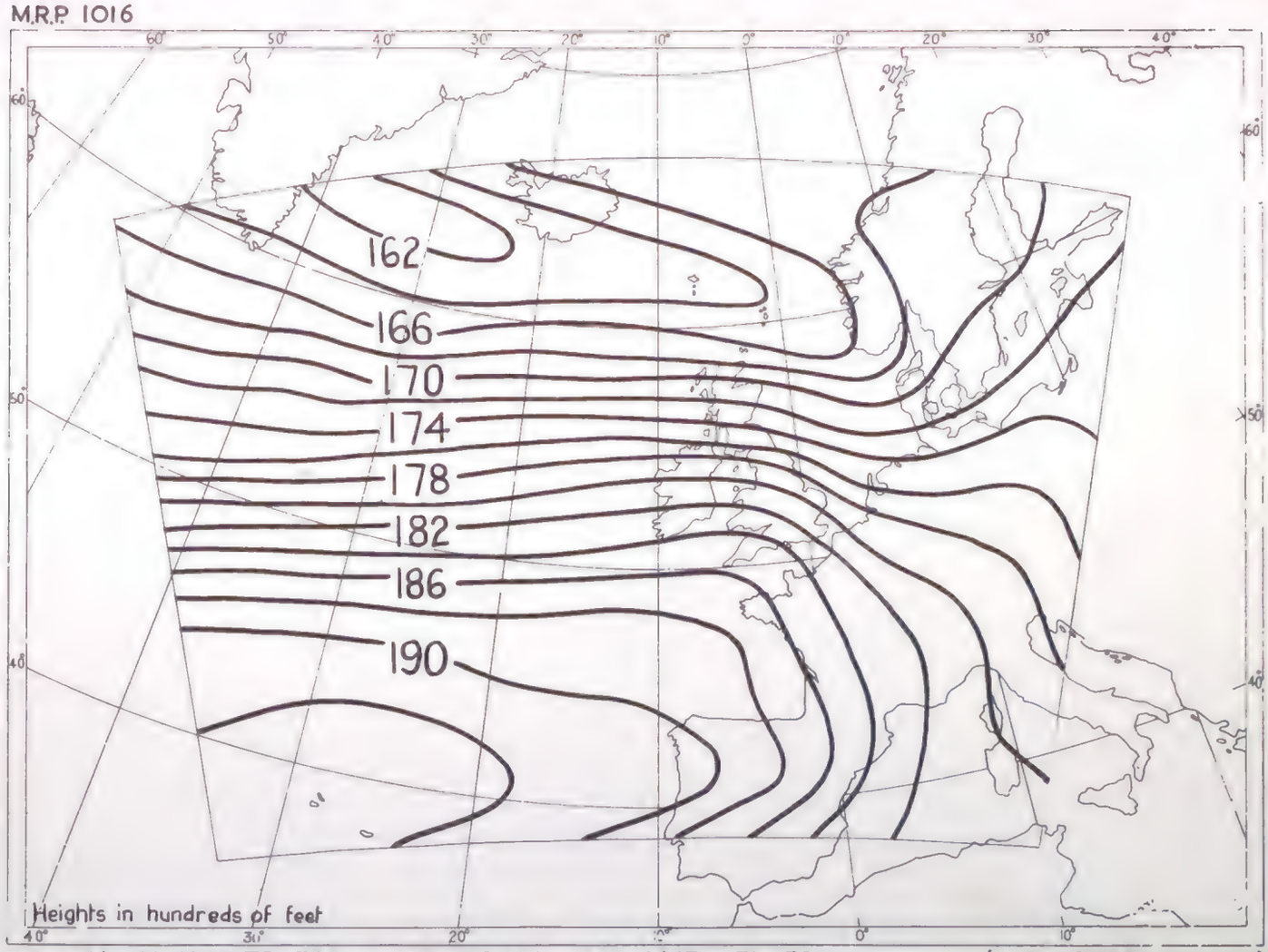

FIG. 4 (e) COMPUTED 500mb CONTOURS 1500 G.M.T., 31·1·52 (SUBJECTIVE ANALYSIS).

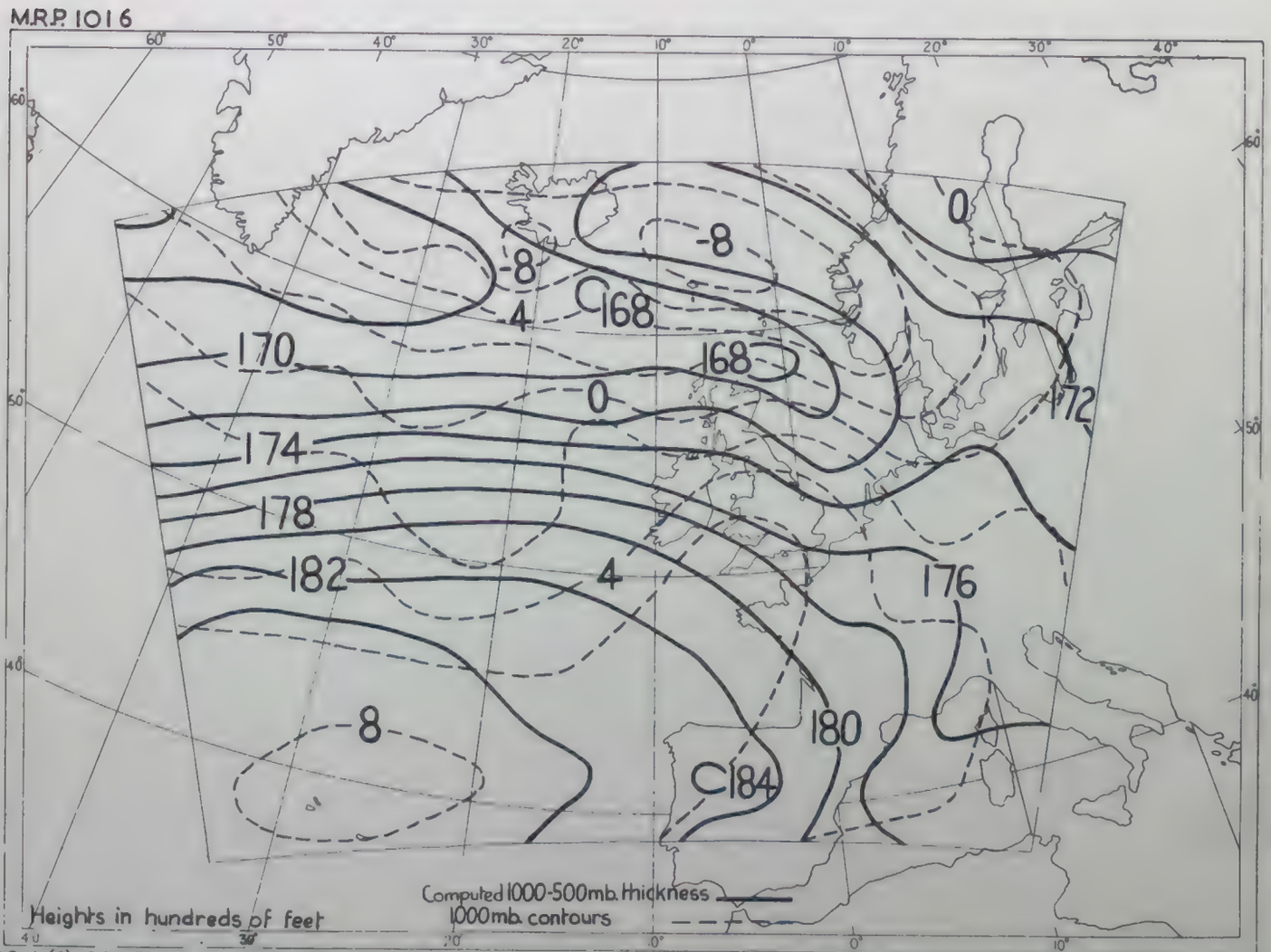

FIG. 4 (f) COMPUTED 1000-500mb. THICKNESS AND 1000mb. CONTOURS 1500 G.M.T. 31·1·52 (SUBJECTIVE ANALYSIS)

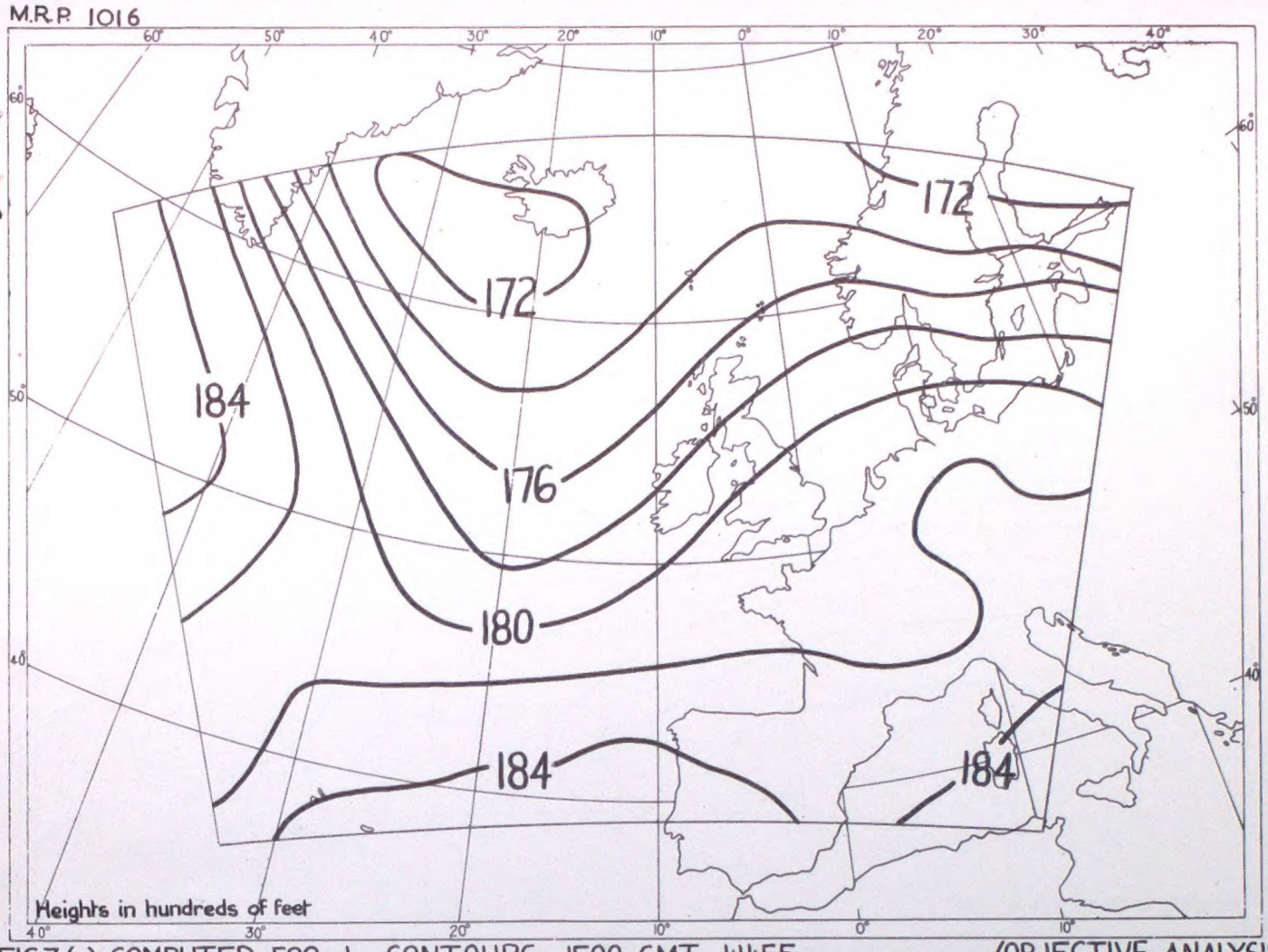

FIG 3(g) COMPUTED 500mb. CONTOURS 1500 GMT. 1:11:55 (OBJECTIVE ANALYSIS)

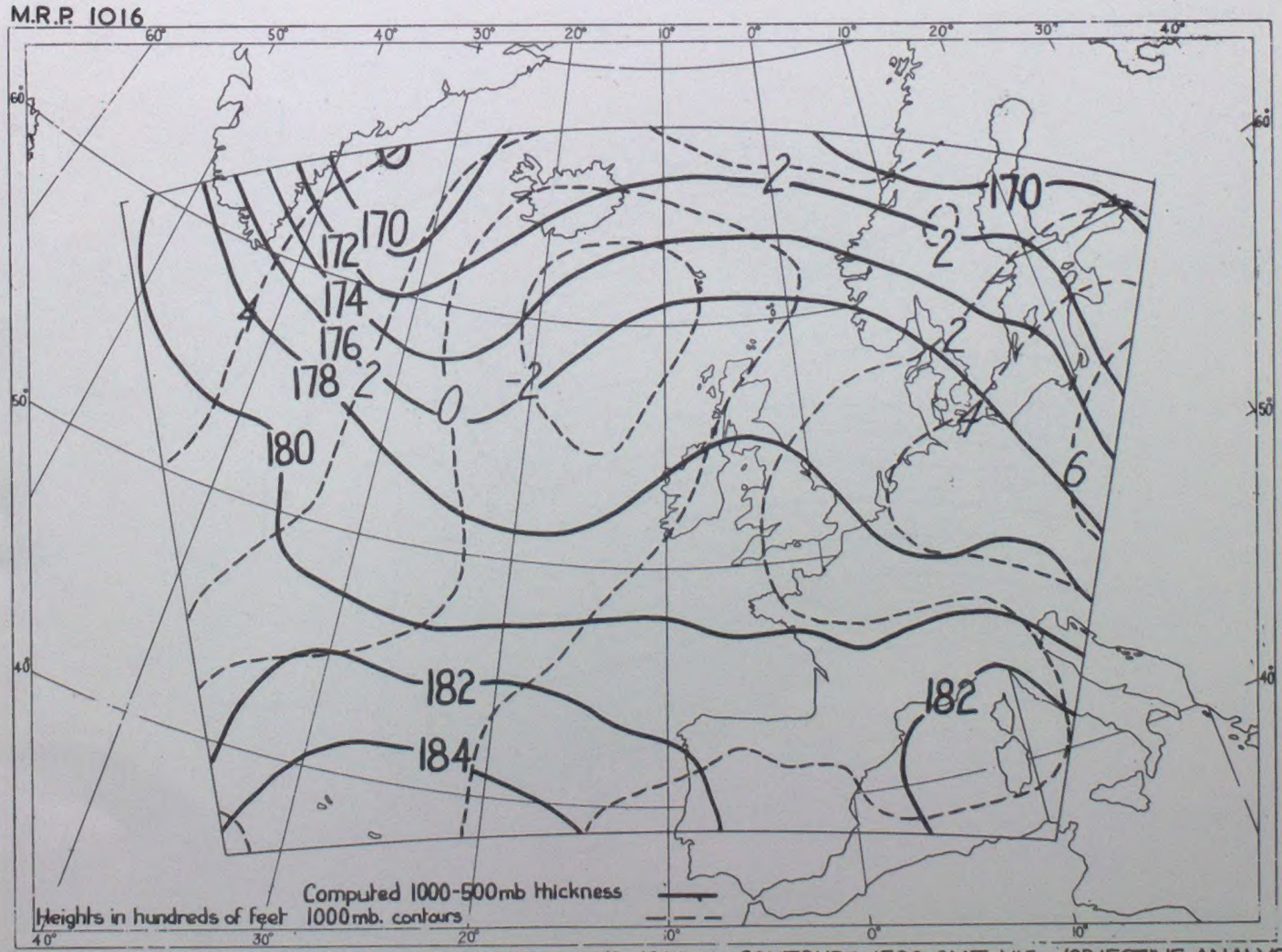

FIG. 3(h) COMPUTED 1000-500mb THICKNESS AND 1000mb. CONTOURS 1500 GMT. 1:11:5 (OBJECTIVE ANALYSIS)

M.R.P. 1016

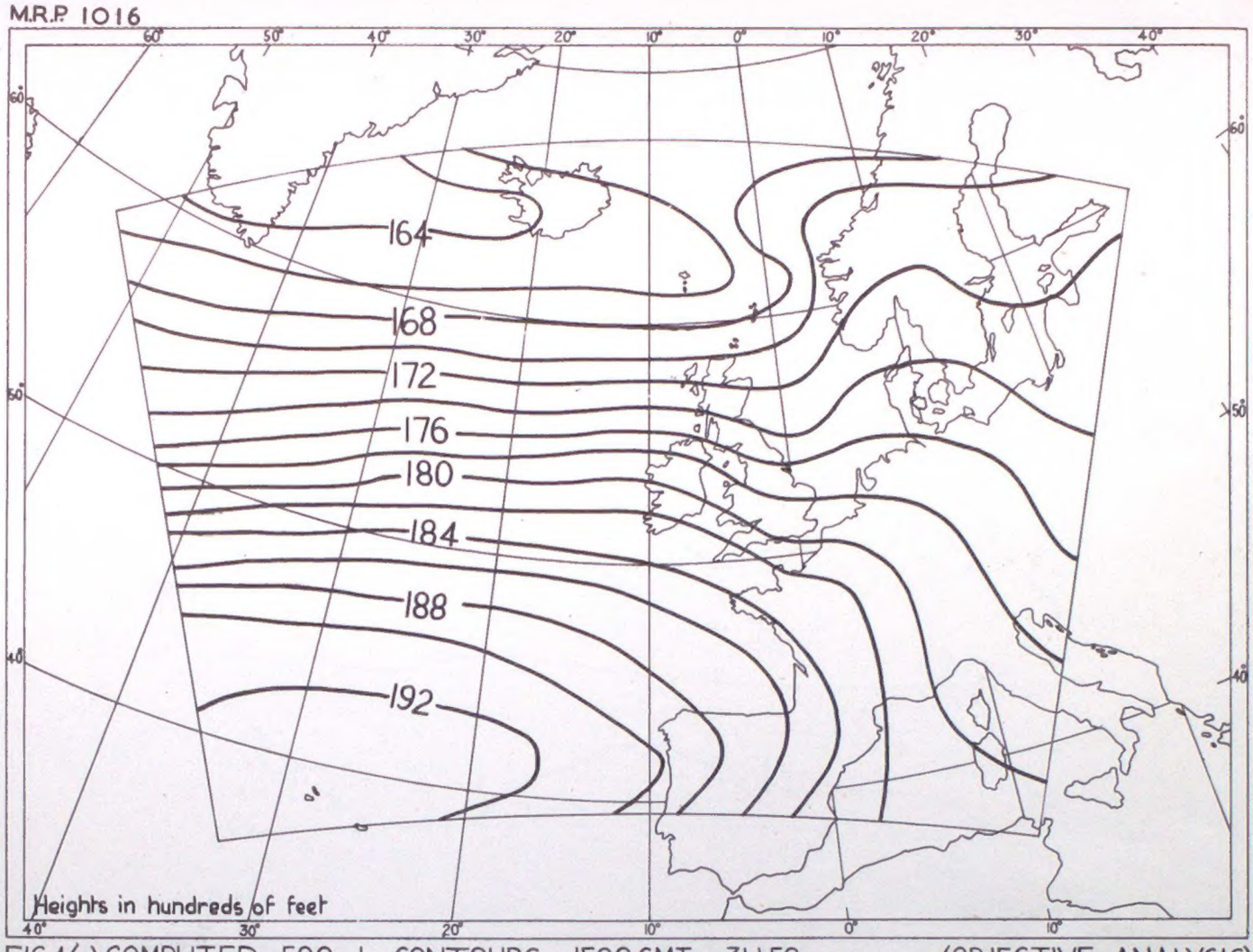

FIG. 4(g) COMPUTED 500mb. CONTOURS 1500 G.M.T. 31:1:52 (OBJECTIVE ANALYSIS)

M.R.P. 1016

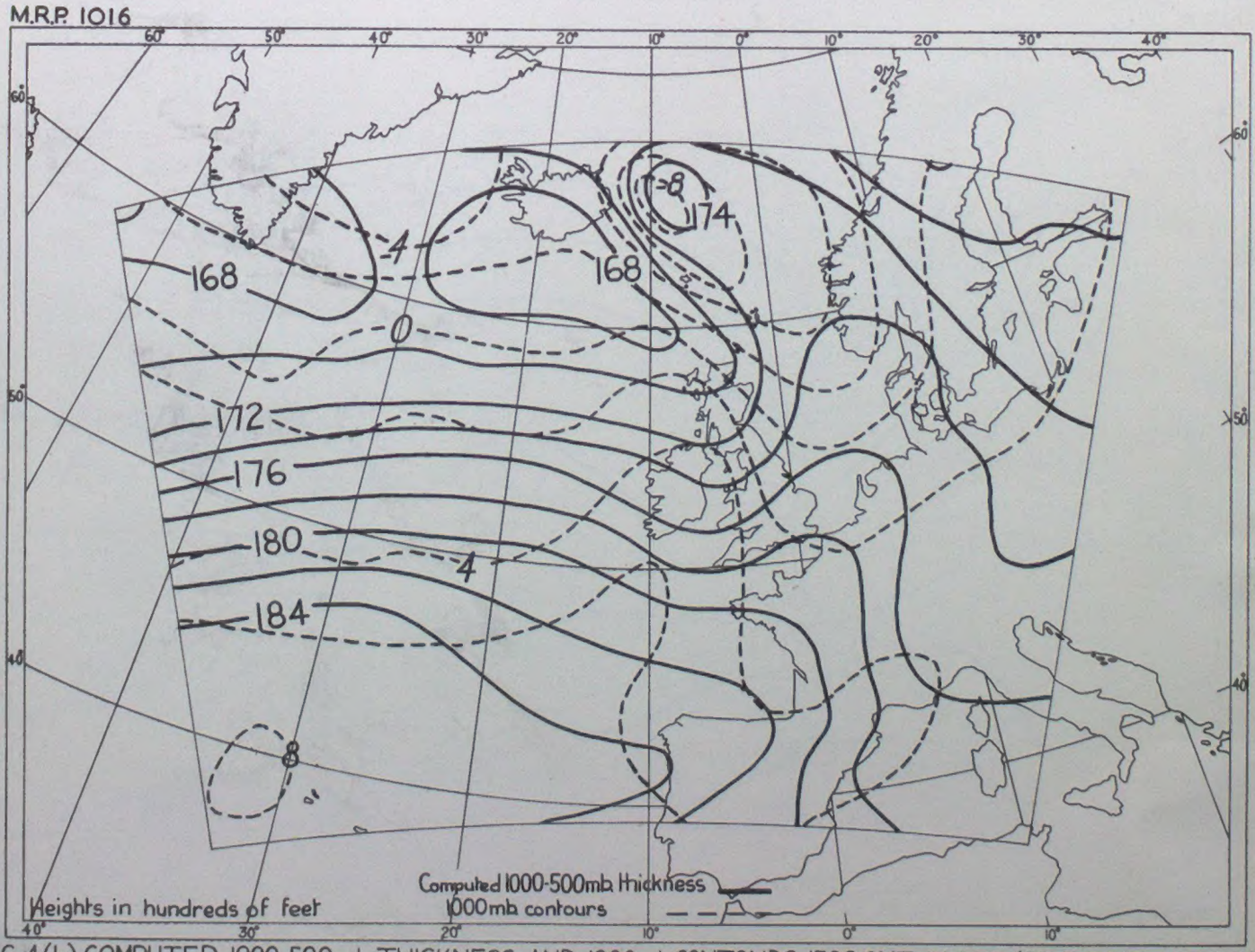

FIG. 4(h) COMPUTED 1000-500mb. THICKNESS AND 1000mb. CONTOURS 1500 G.M.T. 31:1:52 (OBJECTIVE ANALYSIS)

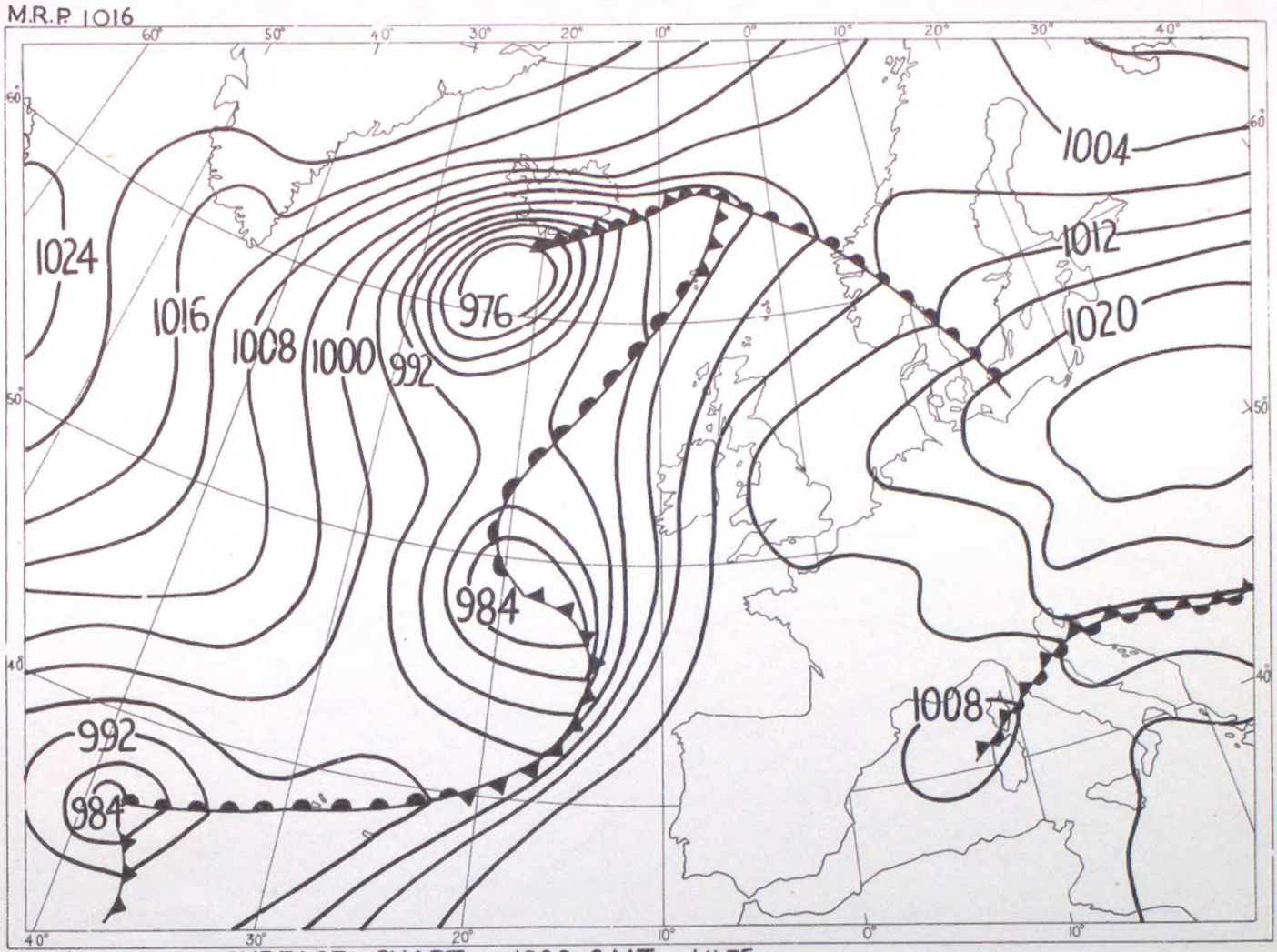

FIG3(i) ACTUAL SURFACE CHART , 1800 G.M.T. 1:11:55

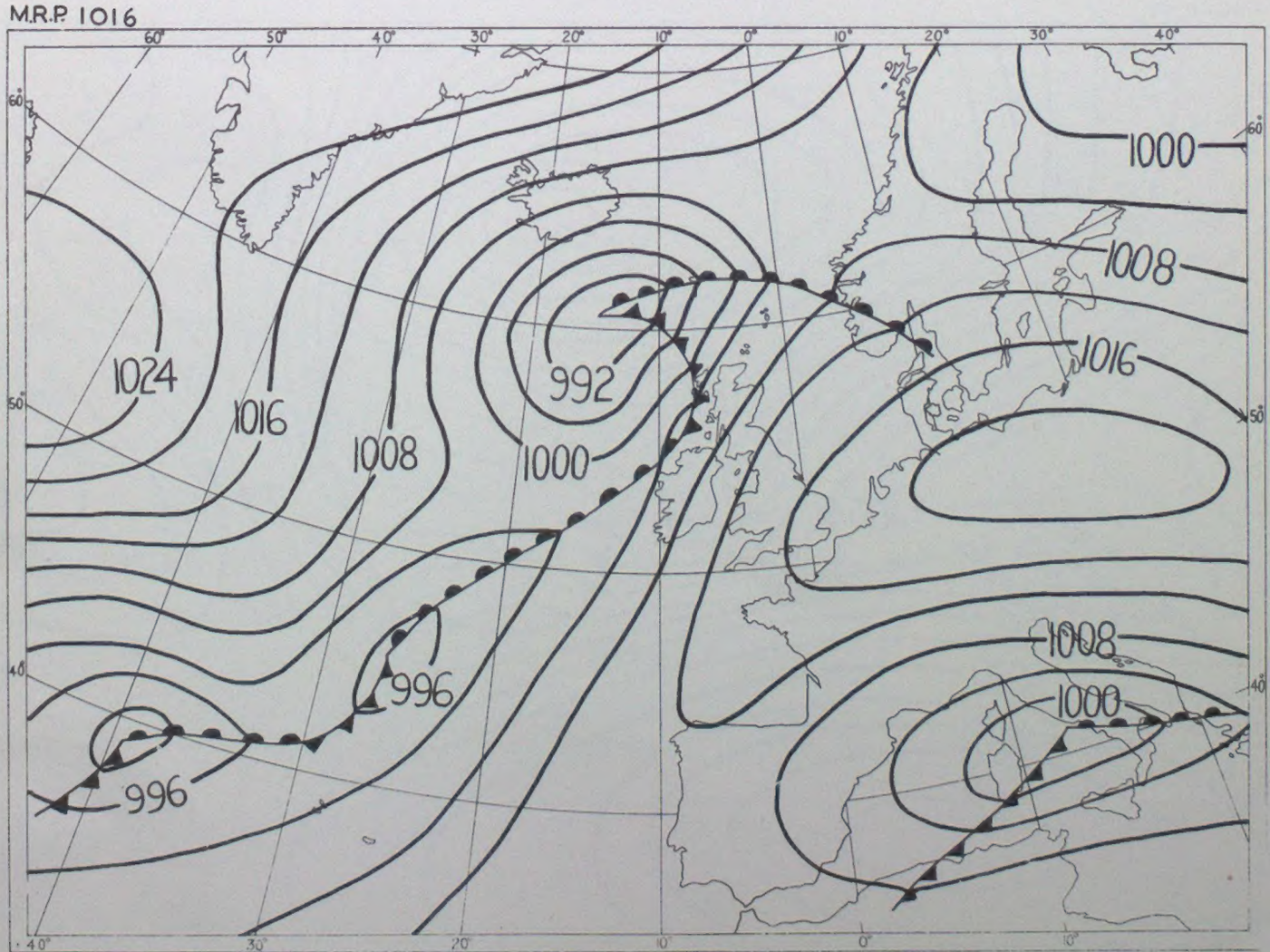

FIG. 3(j) CONVENTIONAL SURFACE FORECAST, 1800 G.M.T. 1:11:55

M.R.P. 1016

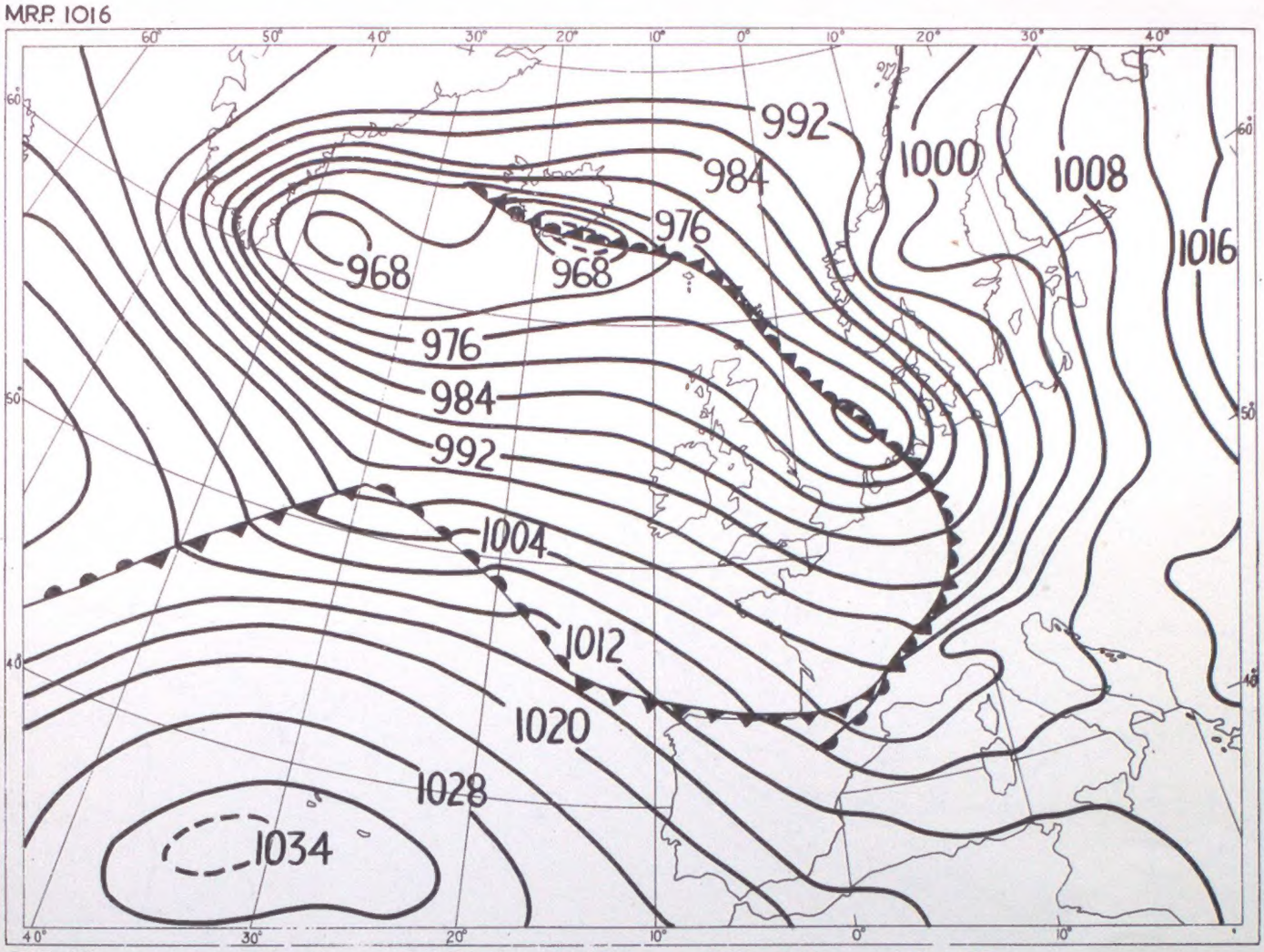

FIG. 4(i) ACTUAL SURFACE CHART 1800 G.M.T. 31:1:52

M.R.P. 1016

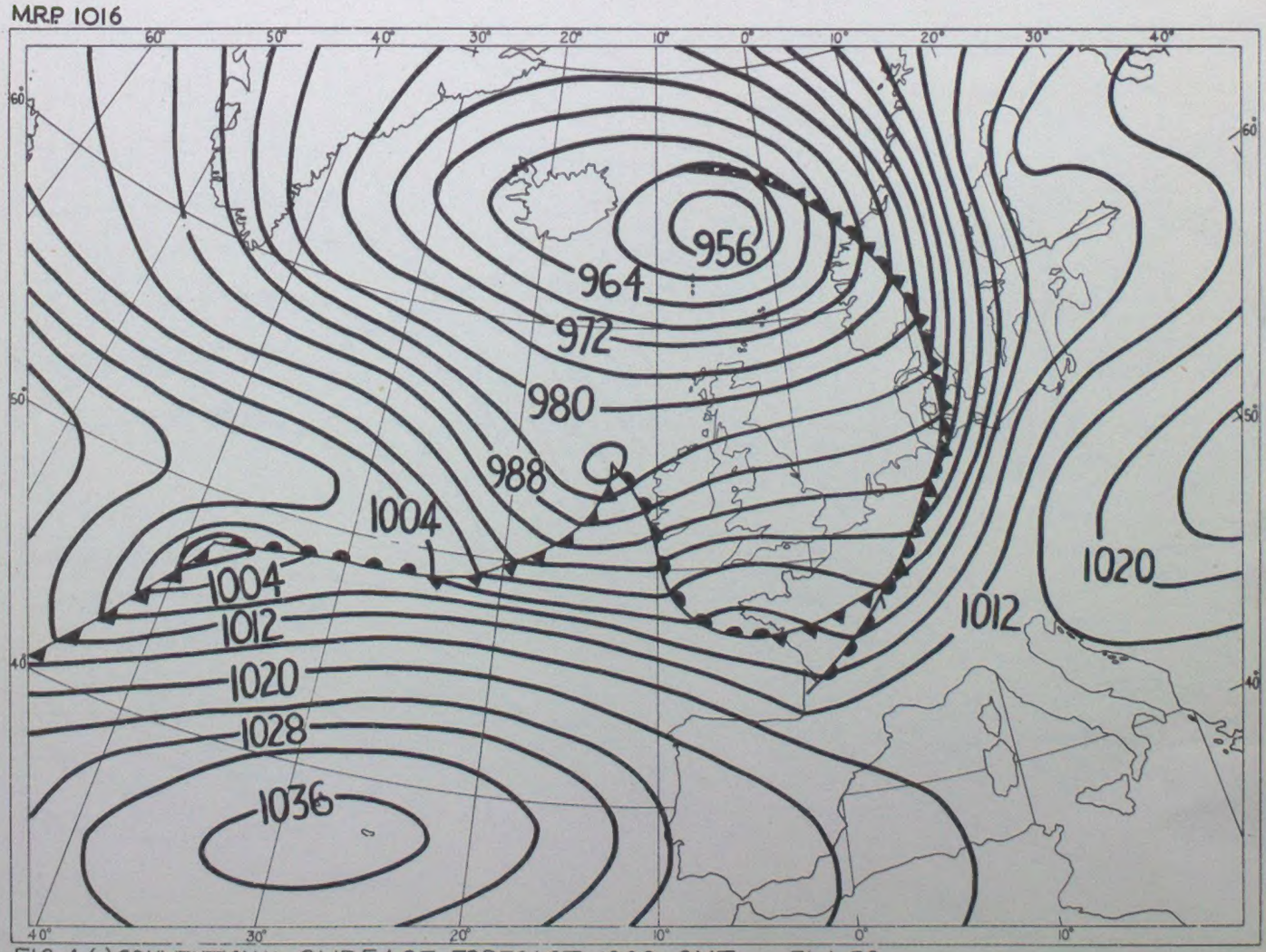

FIG. 4 (j) CONVENTIONAL SURFACE FORECAST 1800 G.M.T. 31:1:52